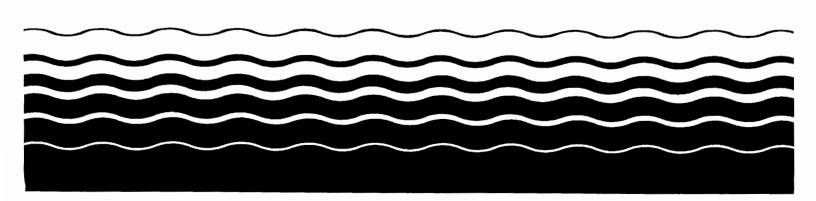
Agency



SEPA Environmental Assessment of **Proposed Revisions to the National Pollutant Discharge Elimination System Regulation** and the Effluent Guidelines for **Concentrated Animal Feeding Operations**



Environmental Assessment of Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and Effluent Limitations Guidelines for Concentrated Animal Feeding Operations

Carol M. Browner Administrator

J. Charles Fox Assistant Administrator, Office of Water

Sheila E. Frace Director, Engineering and Analysis Division

> Donald F. Anderson Chief, Commodities Branch

Patricia Harrigan Environmental Assessor

Engineering and Analysis Division Office of Science and Technology U.S. Environmental Protection Agency Washington, D.C. 20460

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CONTENTS

EXEC	CUTIVE	E SUMMARY	ix
1.	INTR	ODUCTION	1-1
	1.1	BACKGROUND	1-1
	1.2	OVERVIEW OF ANIMAL FEEDING OPERATIONS	1-3
	1.3	ORGANIZATION OF REPORT	
2.		MAL WASTE CHARACTERISTICS AND TRANSPORT TO SURFACE	
	WAT	ERS	
	2.1	QUANTITY OF MANURE GENERATED	
		2.1.1 Total Manure	
		2.1.2 Recoverable Manure	
	2.2	POLLUTANTS OF CONCERN	
		2.2.1 Nutrients	
		2.2.2 Ammonia	
		2.2.3 Pathogens	2-12
		2.2.4 Organic Matter	
		2.2.5 Salts and Trace Elements	2-14
		2.2.6 Antibiotics	2-15
		2.2.7 Hormones	2-15
		2.2.8 Other Pollutants of Concern	2-15
	2.3	TRANSPORT OF MANURE POLLUTANTS TO SURFACE WATER	2-16
		2.3.1 Surface Discharges	2-16
		2.3.2 Other Discharges to Surface Waters	2-18
		2.3.3 Pollutant-specific Transport	
	D.O.		2.1
3.		ENTIAL HAZARDS FROM AFO POLLUTANTS	
	3.1	PRIMARY NUTRIENTS	
		3.1.1 Ecology	
		3.1.2 Human Health	
	3.2	AMMONIA	
		3.2.1 Ecology	
		3.2.2 Human Health	
	3.3	PATHOGENS	
		3.3.1 Ecology	
		3.3.2 Human Health	
	3.4	ORGANIC MATTER	
		3.4.1 Ecology	
		3.4.2 Human Health	
	3.5	SALTS AND TRACE ELEMENTS	
		3.5.1 Ecology	
	2.6	3.5.2 Human Health	
	3.6	SOLIDS	
	3.7	ANTIBIOTICS AND ANTIBIOTIC RESISTANCE	3-15

	3.8	HORN	MONES AND ENDOCRINE DISRUPTION 3-16
	3.9	OTHE	R POLLUTANTS OF CONCERN 3-16
		3.9.1	Gas Emissions
		3.9.2	Particulates
		3.9.3	Pesticides
4.	NATIO	ONAL A	AND LOCAL IMPACTS OF ANIMAL AGRICULTURE 4-1
	4.1		ONAL WATER QUALITY INVENTORY RESULTS 4-1
	4.2		ONAL ANALYSES OF NUTRIENT CONTRIBUTIONS 4-3
		4.2.1	1994 USGS Study on Nitrogen Production from Various Sources 4-3
		4.2.2	1998 USDA Study of Nitrogen and Phosphorus Production Relative to
			Crop Uptake Potential 4-6
		4.2.3	1997 USGS Modeling Study of Nitrogen and Phosphorus Loadings to
			Surface Waters
	4.3	NATI	ONAL ANALYSIS OF SHELLFISH BED IMPAIRMENT 4-17
	4.4	LOCA	L IMPACTS 4-17
		4.4.1	Lake Eucha
		4.4.2	The Chino Basin 4-61
		4.4.3	Lake Waco and the Bosque River Watershed
	4.5	CASE	STUDY SUMMARY 4-63
5.	EFFE	CTS OF	THE PROPOSED REGULATIONS
	5.1	POTE	NTIAL BENEFITS FROM POLLUTANT REDUCTIONS 5-1
	5.2	REPO	RTED BENEFITS OF ANIMAL WASTE MANAGEMENT AND
			TED NON-POINT SOURCE MEASURES IN SELECTED
		WAT	ERSHEDS
		5.2.1	Benefits of Single Practices 5-5
		5.2.2	Benefits of Multiple Practices 5-6

EXHIBITS

EXHIBIT 1-1
Industry Consolidation of Animal Feeding Operations, 1978 - 1992 1-4
EXHIBIT 1-2
Increase in the Average Number of Animal Units per Operation, 1978-1992 1-4
EXHIBIT 1-3
Farms, Number of Head, and Cropland, by Confined Animal Facility Size, 1992 1-5
EXHIBIT 2-1
Manure Production by Both Livestock and Humans
EXHIBIT 2-2
Fraction of Recoverable Manure, by Animal and by State
EXHIBIT 2-3
Estimated Recoverable Manure and Manure Nutrients Generated by Sector 2-6
EXHIBIT 2-4
Primary Nutrients in Both Livestock and Human Manures
EXHIBIT 2-5
The Nitrogen Cycle
EXHIBIT 2-6
The Phosphorus Cycle
EXHIBIT 2-7
Coliform Bacteria in Manure (colonies per cubic foot of manure, as excreted) 2-12
EXHIBIT 2-8
Reported BOD ₅ and COD Concentrations for Manures and Domestic Sewage 2-14
EXHIBIT 3-1
Some Diseases and Parasites Transmittable to Humans from Animal Manure 3-8
EXHIBIT 3-2
Etiology of Waterborne Disease Outbreaks Causing Gastroenteritis 1989-1996 : 3-10
EXHIBIT 4-1 Five Leading Sources of Water Quality Immairment in the United States
Five Leading Sources of Water Quality Impairment in the United States 4-1 EXHIBIT 4-2
Summary of U.S. Water Quality Impairment Survey
EXHIBIT 4-3
Percent of Total Agricultural Impairment Contributed by Animal Agriculture 4-2
EXHIBIT 4-4
Five Leading Causes of Water Quality Impairment in the United States
EXHIBIT 4-5
Proportions of Nitrogen Sources in Selected Watersheds (1987 Base Year) 4-5
EXHIBIT 4-6
Estimated Manure Nitrogen Production from Confined Livestock 4-8
EXHIBIT 4-7
Estimated Manure Phosphorus Production from Confined Livestock 4-9
EXHIBIT 4-8
Potential for Nitrogen Available from Animal Manure to Meet or Exceed
Uptake and Removal on Non-Legume, Harvested Cropland and Hayland 4-10

EXHIBIT 4-9
Potential for Phosphorus Available from Animal Manure to Meet or Exceed
Uptake and Removal on Non-Legume, Harvested Cropland and Hayland 4-11
EXHIBIT 4-10
Predicted Local Nitrogen Yield in Hydrologic Cataloging Units 4-13
EXHIBIT 4-11
Predicted Local Total Phosphorus Yield in Hydrologic Cataloging Units 4-14
EXHIBIT 4-12
Predicted Percentage Contribution of Animal Waste to Local
Total Nitrogen Export from Hydrologic Cataloging Units 4-15
EXHIBIT 4-13
Predicted Percentage Contribution of Animal Waste to Local
Total Phosphorus Export from Hydrologic Cataloging Units 4-16
EXHIBIT 4-14
Shellfish Beds Impaired by Feedlots 4-17
EXHIBIT 4-15
Description of Environmental Incidents and Impacts Tables 4-18
EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters 4-19
EXHIBIT 4-17
Documented Human Health Related Impacts from Swine Operations 4-29
EXHIBIT 4-18
Documented Ecological, Recreational, and Other Impacts from Swine Operations 4-30
EXHIBIT 4-19
Documented Discharges from Poultry Operations to Surface Waters
EXHIBIT 4-20
Documented Human Health Related Impacts from Poultry Operations 4-39
EXHIBIT 4-21
Documented Ecological, Recreational, and Other Impacts from Poultry Operations . 4-40
EXHIBIT 4-22
Documented Discharges from Beef and Dairy Operations to Surface Waters 4-4
EXHIBIT 4-23
Documented Human Health Related Impacts from Beef and Dairy Operations 4-4
EXHIBIT 4-24
Documented Ecological, Recreational, and Other Impacts from Beef and Dairy
Operations
EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple
Animal Types
EXHIBIT 4-26
Documented Human Health-Related Impacts from Operations with Unspecified or
Multiple Animal Types 4-5

EXHIBIT 4-27	
Documented Ecological, Recreational, and Other Impacts from Operations with	
Unspecified or Multiple Animal Types	4-58
EXHIBIT 5-1	
Anticipated Benefits of the CAFO Proposed Regulations	. 5-2

EXECUTIVE SUMMARY

States report that agriculture is the leading source of impairment in the nation's surveyed rivers and lakes. In the states that categorized sources of impacts to rivers in 1998, intensive animal operations accounted for over 15 percent of the total impairment due to agriculture. Manure and other animal wastes from these animal feeding operations (AFOs) can result in human health and potentially significant environmental impacts. Such impacts continue to cause concern despite federal effluent limitation guidelines that address feedlots, which have been in place since 1974. Since the EPA promulgated the original effluent guidelines, there have been persistent reports of discharge and runoff of manure pollutants reaching surface and groundwater and resulting in fish kills and other adverse impacts.

Animal production has undergone significant changes in the past several decades. Between 1987 and 1992, the total number of animal units increased by about 4.5 million (approximately 3 percent). At the same time, the number of facilities has decreased, indicating a consolidation within the livestock industry.

Animal Waste Characteristics

Beef, dairy, swine, and poultry operations generated a total of 291 billion pounds of manure (weight of dry-state or dried manure) in 1997. This figure represents recoverable and non-recoverable manure. Recoverable manure is generally indicative of confined operations, because it is waste that is contained within the production area. The U.S. Environmental Protection Agency (EPA) estimates the amount of manure that is recoverable from each of the four animal sectors addressed by the guidelines to be beef (16 percent), dairy (76 percent), swine (92 percent), and poultry (98 percent).

Animal waste contains a number of pollutants. The presence and concentration of these pollutants may vary depending on the animal species and other factors, such as animal size, maturity, and health, as well as the composition (e.g., protein content) of animal feed.

Nitrogen, an essential nutrient required by all living organisms, exists in fresh manure in organic and ammonium forms. Nitrogen can transform to nitrate, and it is then water soluble and highly mobile in the environment. When farmers apply excess manure as fertilizer to crops, nitrates may run off into surface water and may leach to groundwater. Like nitrogen, phosphorus also exists in animal waste. As animal waste ages, the organic phosphorus mineralizes to inorganic phosphate compounds and becomes available to plants. Organic phosphorus compounds are generally water soluble and may leach through soil to groundwater and run off into surface waters. Inorganic phosphorus attaches to soil particles and may reach surface waters through erosion.

The ammonia content of fresh manure varies among animal species and changes as the manure ages. Ammonia content may increase as organic matter breaks down; it may decrease when volatilization occurs or when nitrate oxidizes to nitrite under aerobic conditions. A major method of transport of ammonia is through atmospheric deposition from airborne emissions.

Livestock manure contains many pathogens, including protozoa, bacteria, and viruses. Multiple species of pathogens may be transmitted directly from a host animal's manure and may increase in number in a waterbody due to loadings of animal manure nutrients. Pathogen contamination from AFOs includes discharges directly to surface waters and discharges from leaching lagoons, and can reach surface waters and groundwater. Soil type, manure application rate, and soil pH are dominating factors in the survivability of bacteria. Type of storage and length of storage also affect bacterial survivability.

Organic compounds in animal manure can enter water directly from feedlots and land application sites. They then undergo decomposition by aquatic bacteria and other microorganisms. In the process, the organisms consume dissolved oxygen, reducing the amount available for aquatic animals. Measures that indicate presence of the organic compounds in manure are the biochemical oxygen demand (BOD) and the chemical oxygen demand (COD). Even after treatment, these measures are much higher for animal waste than for municipal treated waste.

Several other pollutants can reach surface water and groundwater. Dissolved mineral salts and several trace elements (including arsenic, copper, selenium, and zinc) can reach surface waters via discharges directly to the waterbody as well as runoff from land application sites and can leach into groundwater. Although present in small amounts in manure, trace elements may bioconcentrate in plants and animal tissues and persist in the environment. The degradation of animal wastes by microorganisms may produce gases with strong odors. Particulate emissions, pesticides, antibiotics, and hormones also exist in animal waste and may impact the environment.

Human Health Hazards Associated with Animal Wastes

Many constituents of animal waste, including primary nutrients, pathogens, salts, and gases, can affect human health. Elevated nitrate levels in drinking water are a major health concern. In particular, infants are at risk from nitrate poisoning (also referred to as methemoglobinemia or "blue baby syndrome"), which results in oxygen starvation. Nitrate poisoning may increase the risk of birth defects and miscarriages, and is potentially fatal.

Pathogens in animal waste cause many human diseases. These include salmonellosis, cryptosporidiosis, giardiasis, cholera, typhoid fever, and polio. Humans may come into contact with the pathogens via the fecal-oral route, inhalation, or consumption of contaminated water. The protozoan *Cryptosporidium parvum* is of particular concern because it is resistant to conventional drinking water treatment. *Cryptosporidium* can produce gastrointestinal illness, with symptoms such as severe diarrhea.

Salts in animal waste are also a human health hazard. At low levels, salts can increase blood pressure in salt-sensitive individuals, increasing the risk of stroke and heart attack. Trace metal elements in manure can also impact human health. For example, while zinc (a feed additive) is a requirement for human physiology, it may induce toxicity at elevated concentrations.

The primary gases associated with aerobic decomposition include carbon dioxide and ammonia. Gases associated with anaerobic conditions, which dominate in typical, unaerated animal waste

lagoons, include methane, carbon dioxide, ammonia, hydrogen sulfide, and over 150 other compounds. Many of the end products can produce negative impacts, including strong odors.

Ecological Effects Associated with Animal Wastes

Animal waste can also have an effect on the natural ecosystem. Perhaps the most documented impact of nutrient pollution is the increased surface water eutrophication (nutrient enrichment) and its effects on aquatic ecosystems. Eutrophication causes the enhanced growth and subsequent decay of algae, which can lower dissolved oxygen content of a waterbody to levels insufficient to support fish and invertebrates. In some cases, this situation can produce large areas devoid of life because of a lack of sufficient dissolved oxygen. An example of this is the "Dead Zone," a 10,000 km² area in the Gulf of Mexico. Researchers believe the Dead Zone is caused by excess chemical fertilizer; however, nutrients from animal waste have also contributed to the problem. Eutrophication may increase the incidence of harmful algal blooms, which release toxins as they die and can severely impact wildlife as well as humans.

Parasites, bacteria, and viruses in animal waste may be harmful to wildlife. Certain bacteria in livestock waste cause avian botulism and avian cholera, which have killed thousands of migratory waterfowl. Shellfish can concentrate a broad range of microorganisms in their tissues, providing a pathway for pathogen transmission to predator organisms.

Ammonia is highly toxic to aquatic life and is a leading cause of fish kills. It is of environmental concern because it exerts a direct oxygen demand on the receiving water as it breaks down. Ammonia loadings can contribute to accelerated eutrophication of surface waters. Also, organic matter in surface waters supports increased microbial population and activity, and as these microorganisms degrade the organic matter, the amount of dissolved oxygen available to other aquatic organisms decreases.

Salts from manure can impact the ecosystem. In fresh water, increasing the salinity can disrupt the balance of the ecosystem. On land, salts can become toxic to plants and deteriorate soil quality by reducing permeability and generally impacting physical condition. Trace elements in manure can impact plants, aquatic organisms, and terrestrial organisms. For example, metals such as zinc (a feed additive) can accumulate at high concentrations in soil and become toxic to plants.

National and Local Impacts from Animal Agriculture

Several analyses have estimated nationwide impacts from animal operations. First, in an analysis of nitrogen sources (including manure, fertilizers, point sources, and atmospheric deposition) in 107 U.S. watersheds, the U.S. Geological Survey (USGS) found that proportions of nitrogen originating from various sources differ according to climate, hydrologic conditions, land use, population, and physical geography (Puckett, 1994). In several watersheds (particularly in the South and Northeast), manure nitrogen accounts for a large portion of the total nitrogen added to the watershed.

In a second analysis, Lander et al. (1998) estimated the quantity of nutrients available from confined livestock manure relative to crop growth requirements, by county, based on data from the 1992 Census of Agriculture (USDC/Census Bureau, 1994). Recoverable manure nitrogen exceeded crop system needs in 266 counties, and recoverable phosphorus exceeded crop system needs in 485 counties.

A third analysis, by Smith et al. (1997), modeled transport of manure nutrients to surface water. The authors found that animal waste is a significant source (relative to other local sources) of instream nutrient concentrations in many watershed outlets, particularly in the central and eastern United States. They also conclude that livestock waste contributes more than commercial fertilizer application to total phosphorus exported from local sources (independent of upstream sources).

The EPA has also documented local impacts. In Oklahoma, Lake Eucha has very high nutrient loads associated with poultry production operations. In Florida, Lake Okeechobee has experienced significant effects of phosphorus loadings from AFOs. In southeastern Delaware and the Eastern Shore of Maryland, where poultry production is widespread, over 20 percent of wells have nitrate levels exceeding the Maximum Contaminant Level (MCL) set by the EPA's Office of Ground Water and Drinking Water. Furthermore, localities have reported various ecological impacts associated with releases from AFOs, including eutrophication and fish kills. Over a 10-year period, localities have also reported nearly 100 individual fish kill events associated with spills and discharges from AFOs.

This Report

Unlike environmental assessments prepared to support other effluent guidelines, this report focuses on the qualitative impacts on human health and the environment associated with releases of wastes to surface water from concentrated animal feeding operations (CAFOs). The EPA is not currently able to quantitatively evaluate all human health and ecosystem benefits associated with water quality improvements from reduced releases of CAFO wastes. The EPA is even more limited in its ability to assign monetary values to those benefits. The economic benefit analysis is available in the benefit report, titled "Environmental and Economic Benefits of the NPDES/ELG CAFO Rules" and located in section 9.5 of the public record.

To present a sense of the scope of the problem, this report relies on state and federal information, as well as news articles and data collected by environmental advocacy groups. While data from government agencies are more reliable, the resources are not available to thoroughly track CAFO-related releases of pollutants to the environment and the resulting environmental and human health impacts. The intention of this more inclusive approach is to provide a sense of the possible scope of the impacts until state and federal agencies can fully document them.

1. INTRODUCTION

1.1 BACKGROUND

Animal waste can have a negative impact on surface water, ground water, soil, and air. While there are many sources of water pollution, states report that agriculture is the leading source of impairment in the nation's surveyed rivers and lakes. Furthermore, nutrients and pathogens account for a large percentage of contaminants found in the nation's impaired waters (USEPA, 2000a).

Animal feeding operations (AFOs or feedlots) can pose a number of risks to human health and the environment, mainly because of the significant amount of animal manure they generate. In 1997, farm animals generated an estimated 291 billion pounds (132 million metric tons) of manure (dry-state basis) (USDA/NRCS, 2000). This figure far exceeds the estimated 49 billion pounds (22 million metric tons) of human sanitary waste produced. Since the calculations handle human and animal wastes differently, this comparison does not provide an indication of relative environmental impact; however, it does indicate the significance of animal waste as a potential source of pollution.

AFOs contribute manure pollutants to the environment via discharges directly into surface water, surface runoff, leaching into soil and ground water, and volatilization/deposition. Sources of these pollutants include animal confinement areas, pastures, treatment and storage lagoons, manure stockpiles, and land application fields. Organic matter, ammonia, nutrients (particularly nitrogen and phosphorus), solids, pathogens, and odorous compounds are the pollutants most commonly associated with animal waste. Animal waste is also a source of salts and trace elements, and to a lesser extent, pesticides, antibiotics, and hormones.

Manure can be a valuable fertilizer and soil conditioner, but in many cases it is applied in excess of crop nutrient requirements due to manure nutrient ratios that differ from crop needs, and/or lack of available nearby land on which to spread the manure. This problem has been of increasing concern as more concentrated feeding operations maintain greater numbers of animals.

In surface water, the waste's oxygen demand and ammonia content can directly result in fish kills and reduced biodiversity. Solids can increase turbidity and suffocate benthic organisms. Nitrogen and phosphorus can contribute to eutrophication and associated algae blooms. These blooms can produce negative aesthetic impacts and increase the costs of drinking water treatment. Turbidity from the blooms can reduce penetration of sunlight in the water column and thereby limit growth of seagrass beds and other submerged aquatic vegetation, which serve as critical habitat for fish, crabs, and other aquatic organisms. Decay of algae blooms (as well as nighttime algal respiration) can depress oxygen levels, leading to fish kills and reduced biodiversity. Eutrophication is also a factor in blooms of toxic algae and other toxic microorganisms, such as *Pfiesteria piscicida*, which can affect human health as well as animal health. Pathogens and nitrogen in animal waste can also affect human and animal health.

¹USDA's National Resources Conservation Service calculated animal waste figures using the 1997 Census of Agriculture (USDA/NASS, 1999) and the procedures in Lander et al. (1998).

Nitrogen in manure is easily transformed into its nitrate form, which can be transported to drinking water sources and result in potentially fatal health risks to infants. Trace elements in manure may also present human health and ecological risks. Salts can contribute to salinization and disruption of ecosystems. Antibiotics, pesticides, and hormones may have low-level, long-term human health and ecological effects.

Ground water sources of drinking water can have impacts from nitrates, pathogens, salts, and other contaminants from manure. Ground water is typically more prone than surface water to contamination by nitrates, in particular. In fact, the EPA found that nitrate is the most widespread agricultural contaminant in drinking water wells and estimates that 4.5 million people are exposed to elevated nitrate levels from wells (USEPA, 1990).

In soils, salts and trace elements from land-applied manure can accumulate and become toxic to plants. Salts can deteriorate soil quality by leading to reduced permeability and poor tilth. Crops may provide a human and animal exposure pathway for trace elements and pathogens.

Air emissions from volatilization occurring at AFOs also produce environmental impacts. Odors from anaerobic waste decomposition are particularly offensive. Odors can produce mood disorders such as tension, depression, and fatigue (Schiffman et al., 1995; Thu, 1995). Many odor-causing substances (e.g., ammonia, hydrogen sulfide, and organic dusts) can also cause physical effects. Furthermore, volatilized ammonia can be redeposited on the earth and contribute to eutrophication of surface waters. Methane emissions from anaerobic waste lagoons are a concern because they increase greenhouse gas concentrations.

Such impacts continue to cause concern despite federal effluent limitation guidelines (ELGs, "effluent guidelines," or "guidelines") that have been in place for feedlots since 1974. Essentially, these guidelines apply to large operations and prohibit discharges to surface waters except when chronic or catastrophic rainfall events cause an overflow from a containment system. The current regulations do not specifically address discharges that may occur when wastes are applied to soil.

To help address the various concerns outlined above, the EPA is currently revising the feedlots effluent limitation guidelines. This report presents the environmental assessment of the proposed regulations for the pork, poultry, beef, and dairy sectors of concentrated animal feeding operations (CAFOs). Briefly, each animal sector is composed of:

• pork: facilities that produce mature or immature swine;

• poultry: facilities that produce laying hens, broilers, and turkeys;

• beef: facilities that produce all cattle—this includes veal and replacement

heifers and excludes mature dairy cattle; and

• dairy: facilities that produce mature dairy cattle, whether milked or dry.

1.2 OVERVIEW OF ANIMAL FEEDING OPERATIONS

Animal production industries have undergone significant changes in the past several decades. Domestic and export market forces, technological changes, and industry adaptations have promoted expansion in the number of confined production units. This includes:

- growth in both existing and new areas;
- integration and concentration of some industries;
- · geographic separation of animal production and feed production operations; and
- the concentration of large quantities of manure and wastewater on farms and in some watersheds (USDA/USEPA, 1999).

In terms of production, the total number of animal units produced in the U.S. increased by about 4.5 million (approximately three percent) between 1987 and 1992. During the same period, however, the number of AFOs decreased, indicating a consolidation within the industry overall and greater production from fewer, larger AFOs (USGAO, 1995b). These changes are not uniform across animal type or across the country.

Exhibits 1-1 and 1-2 illustrate the consolidation of animal production between 1978 and 1992. The number of operations decreased significantly for most major animal types during this period (Exhibit 1-1). At the same time, the average number of animals per operation increased significantly (Exhibit 1-2).

EXHIBIT 1-1 Industry Consolidation of Animal Feeding Operations 1978 - 1992

Compiled from data in USGAO (1995b).

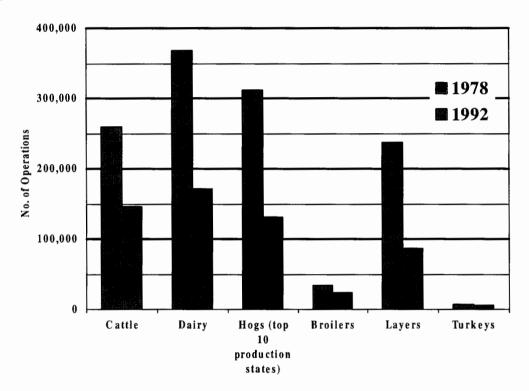


EXHIBIT 1-2 Increase in the Average Number of Animal Units per Operation, 1978-1992

Animal Type	Increase in Animal Units/Operation
Swine	134%
Layers	176%
Broilers	148%
Turkeys	129%
Beef Cattle	56%
Dairy Cattle	93%

Derived from data in USGAO (1995b).

Confined AFOs range in size from small-scale operations with few animals to large, intensive production facilities. Letson and Gollehon (1996) analyzed 1992 Census of Agriculture data (USDC/Census Bureau, 1994) to estimate the distribution of confined animals among various farm sizes (Exhibit 1-3). Their analysis shows that for all animal types, small facilities accounted for a large share of farms, but a small percentage of animals. Larger farms were less numerous, but maintained a disproportionately greater percentage of animals. The greatest proportion of layers and beef cattle were raised on large farms, whereas medium-sized farms accounted for the greatest proportion of swine, broilers, turkeys, and dairy cattle.

EXHIBIT 1-3
Farms, Number of Head, and Cropland, by Confined Animal Facility Size, 1992

Animal Type		nall AUs)	Med (50 to 99		Lar (> 1,000	
	Number	Percent	Number	Percent	Number	Percent
Swine						
Number of farms	115,830	56%	88,042	43%	2,578	1%
Total Head (1,000s)	3,089	5%	38,984	68%	15,270	27%
Total Cropland (1,000 acres)	17,029	30%	37,121	66%	1,795	3%
Layers						
Number of farms	81,903	93%	5,733	6%	599	1%
Total Head (1,000s)	4,033	1%	137,366	39%	209,911	60%
Cropland (1,000 acres)	8,848	90%	881	9%	149	2%
Broilers						
Number of farms	17,657	49%	16,704	47%	1,398	4%
Total Head (1,000s)	2,193	<1%	684,507	73%	246,667	26%
Total Cropland (1,000 acres)	2,207	58%	1,371	36%	211	6%
Turkeys						
Number of farms	7,379	70%	2,911	28%	276	3%
Total Head (1,000s)	892	1%	64,019	74%	21,703	25%
Total Cropland (1,000 acres)	848	60%	535	38%	33	2%
Beef						
Number of farms	134,847	92%	11,411	8%	943	1%
Total Head (1,000s)	995	10%	1,941	19%	7,098	71%
Total Cropland (1,000 acres)	34,199	75%	10,160	22%	1,117	2%
Dairy						
Number of farms	43,700	28%	110,700	71%	939	1%
Total Head (1,000s)	238	3%	8,002	84%	1,252	13%
Total Cropland (1,000 acres)	6,097	16%	32,524	83%	515	1%

Source: Letson and Gollehon (1996).

The Letson and Gollehon (1996) analysis also provides useful insight regarding the cropland held by various sizes of AFOs. As shown in Exhibit 1-3, medium and large poultry operations (particularly layer facilities and beef operations) account for a large percentage of animals, but a small percentage of cropland on which to apply manure. Pork and dairy operations exhibit a similar characteristic for large farms. The amount of cropland ultimately influences animal waste disposal options. Historically, farm enterprises integrated crop and animal production by using the manure generated to fertilize crops, constituting a crucial element of manure management. Such integrated pork and dairy operations are still common, particularly in the eastern Corn Belt. However, the breeding and raising phases of livestock production increasingly occurs in large-scale, specialized operations. This trend toward high-volume commercial enterprises separates the locations of manure generation and cropland available for its application (Letson and Gollehon, 1996).

1.3 ORGANIZATION OF REPORT

This report presents a water-quality-based environmental impact assessment of the proposed regulations for swine, poultry, beef, and dairy CAFOs. Chapter 2 quantifies the amount of manure and total solids generated by swine, poultry, beef, and dairy operations as well as by other livestock and humans. Chapter 2 also provides information on animal manure constituents. Chapter 3 describes the potential human health and ecological hazards from manure pollutants. Chapter 4 discusses studies that estimate the potential environmental impact of animal waste at the national level and describes other reported impacts. Finally, Chapter 5 describes potential and reported benefits from the implementation of proposed management practices to control wastes from animal feeding operations.

To present a sense of the scope of the problem, this report relies on state and federal information, as well as news articles and data collected by environmental advocacy groups. While data from government agencies are considered more reliable, the resources are not available to thoroughly track CAFO-related releases of pollutants to the environment and the resulting environmental and human health impacts. This more inclusive approach is intended to provide a sense of the possible scope of the impacts until state and federal agencies can fully document them.

2. ANIMAL WASTE CHARACTERISTICS AND TRANSPORT TO SURFACE WATERS

Animal feeding operations generate large volumes of waste of the following types:

- animal manure and urine:
- hair, feathers, and corpses;
- · bedding and spilled feed;
- · wash-flush water; and
- other processing wastes.

Many of these wastes are convertible to useful resources, such as fertilizer, soil conditioner, and feed (Shih, 1993; Edwards and Daniel, 1992a; USDA, 1992). However, these wastes can be a source of environmental degradation when improperly managed. In many cases, manure is applied in excess of crop nutrient requirements, due to manure nutrient ratios that differ from crop needs and/or lack of available nearby land. For example, the U.S. Fish and Wildlife Service estimates that the amount of phosphorus currently excreted by livestock in Nebraska exceeds what can currently be applied to farm fields at agronomic rates statewide (USFWS, 2000). This problem has received increasing attention as livestock operations have become more concentrated, with a trend toward more animals on fewer farms and less land. Incidents of discharges from waste storage lagoons, excessive runoff, leaking lagoons, and offensive odors have heightened public awareness and concerns about environmental impacts from AFOs.

Although many of the above-mentioned wastes can pose environmental risks, this chapter focuses on the characteristics of manure, which is often cited as a significant contributor to water quality degradation (USEPA, 1997a). In general, pollutant production figures reported here are based on 1997 data, the most readily available Census of Agriculture data (USDA/NRCS, 2000; USDA/NASS, 1999). USDA's Natural Resources Conservation Service (NRCS) estimated the quantities of manure and primary nutrients generated by livestock. NRCS based its approach on Lander et al. (1998), which provides a more detailed description of the methods and data sources used.

2.1 QUANTITY OF MANURE GENERATED

2.1.1 Total Manure

The large quantity of animal waste helps demonstrate why proper handling and disposal are essential in limiting environmental risks from manure. Animal manure is significantly more abundant than human waste. USDA's National Resources Conservation Service estimated that 291 billion pounds of manure measured on a wet basis (132 million metric tons when dried) was generated in 1997 from swine, poultry, and beef and dairy cattle (USDA/NRCS 2000) (see

Exhibit 2-1).² By comparison, the human sanitary waste production for that year was only 49 billion pounds (22 million metric tons total solids, dry-weight basis) (USDA/NRCS, 1996). This comparison, however, cannot be used as a surrogate for the relative extent of environmental impacts, since human and animal wastes are handled differently. For example, human sanitary waste is typically treated at a wastewater treatment plant, with the liquid effluent being discharged after treatment to surface water and the residual solids (sludge, or biosolids) being land applied, landfilled, or incinerated. Animal waste is typically land applied in its entirety, without an associated point source discharge (if properly applied). Nevertheless, the figures provide a sense of the significance of the total animal waste problem, especially in light of industry trends toward increased concentration of animals on farms. The figures are also relevant when considering that disposal of human waste is highly regulated, but disposal of animal waste has been largely unregulated.

EXHIBIT 2-1 Manure Production by Both Livestock and Humans

	Average	Pounds Per 1,000 Pounds L	,000 Pounds Live Unit Weight Per Day			
Species	Mass of Species (pounds)	Wet-Weight Manure a	Dry-Weight Manure b			
Swine	135	84	8.2			
Layer	4.0	64	16			
Broiler	2.0	85	21			
Turkey	15	47	12			
Beef	800	58	6.9			
Dairy	1,400	86	10			
Human	150	30	3.3			

Sources: Livestock data are "as excreted" and are from ASAE (1999); human waste data are "as excreted" and are from USDA/NRCS (1996).

2.1.2 Recoverable Manure

Although the above figures give a good indication of the magnitude of the total animal waste problem, they are not the best indicators of the problem that the proposed regulations address, because much of the total manure is generated by grazing or pastured animals, which are not the subject of the proposed regulations. Instead, the regulations address the manure generated by confined animal facilities, which is considered recoverable manure because waste is contained within the production area. Recoverable manure may include scraped manure, stored slurry

Values rounded to two significant figures.

^a Includes feces and urine as voided.

^b Calculated using average solids content for each category, based on data from USDA/NRCS (1996).

²These quantities reflect the most recent estimates by USDA of manure generation from livestock operations, using data from the 1997 Census of Agriculture (USDA/NASS, 1999) and an approach developed by Lander et al. (1998). USDA's estimates are calculated on a wet manure basis, but expressed on a "dry-state" basis (to adjust for water content). Previous studies have reported a wide range of manure generation estimates for livestock and poultry operations that vary depending on the approach used and on whether the load is estimated on a wet or dry basis.

manure, lagoon effluent, and poultry litters, and may be applied later to croplands as fertilizer (Westerman et al., 1985).

It is important to estimate the amount of recoverable manure produced, not only to provide a good representation of the amount produced by confined animal operations, but also because recoverable manure may be a usable resource. For each state, Exhibit 2-2 lists the fraction of manure produced by major animal sectors that is recoverable. Lander et al. (1998) prepared these estimates using state survey responses from a study by Van Dyne and Gilbertson (1978).

As presented in Exhibit 2-2, nearly all manure (90 to 100 percent) from layers and broilers in the major producing states was recoverable. Turkey manure recovery ratios varied more widely in the top producing states. For example, recovery ratios ranged from 70 to 100 percent in North Carolina, South Carolina, Texas, Virginia, and Wisconsin, whereas they were only 20 to 45 percent in California, Michigan, and Minnesota. Approximately 90 percent of all swine manure in North Carolina was recoverable. In other major pork producing states, manure recovery ratios ranged from 65 to 85 percent. In top producing beef states, only five to ten percent of the manure from grazing cattle was recoverable, whereas 60 to 90 percent of the manure from fattened cattle was recoverable. Recovery ratios for milk cows in top producing states ranged from 75 to 90 percent.

EXHIBIT 2-2 Fraction of Recoverable Manure, by Animal and by State (Top Ten Producing States Indicated by Bold Font)

State	Beef (Grazing)	Beef (Fattened)	Milk	Swine (Breeding)	Swine (Other)	Laying Hen/Pullet	Pullets (<3 mos.)	Broilers	Turkeys (slaughter)	Turkeys (breeding)
AL	0.10	0.70	0.40	0.75	0.75	0.95	0.95	0.98	0.85	0.85
AZ	0.05	0.85	0.80	0.85	0.85	0.90	0.90	0.90	0.65	0.65
AR	0.10	0.50	0.50	0.50	0.50	0.80	0.80	0.95	0.70	0.70
CA	0.05	0.85	0.80	0.85	0.85	1.00	1.00	1.00	0.20	0.20
со	0.05	0.85	0.80	0.85	0.85	0.95	0.95	0.95	0.65	0.50
СТ	0.10	0.85	0.90	0.80	0.80	1.00	1.00	0.95	0.95	0.95
DE	0.10	0.85	0.80	0.80	0.80	0.90	0.90	0.95	0.95	0.95
FL	0.00	0.00	0.50	0.40	0.40	0.95	0.95	0.95	0.85	0.85
GA	0.00	0.75	0.70	0.50	0.50	0.90	0.90	0.95	0.85	0.85
ID	0.00	0.85	0.95	0.70	0.70	0.90	0.90	0.90	0.65	0.65
IL	0.10	0.60	0.80	0.70	0.70	1.00	1.00	1.00	0.95	0.95
IN	0.10	0.75	0.60	0.80	0.80	0.95	0.95	0.95	0.95	0.95
IA	0.10	0.63	0.87	0.80	0.80	0.99	0.99	0.99	0.69	0.69
KS	0.05	0.75	0.85	0.80	0.80	0.95	0.95	0.95	0.75	0.75
KY	0.08	0.70	0.70	0.60	0.60	0.80	0.80	0.80	0.80	0.80
LA	0.00	0.80	0.50	0.80	0.80	1.00	1.00	1.00	0.80	0.80
ME	0.10	0.85	0.80	0.80	0.80	0.90	0.90	0.95	0.95	0.95
MD	0.10	0.85	0.80	0.80	0.80	0.90	0.90	0.95	0.95	0.95
MA	0.10	0.85	0.80	0.80	0.80	0.90	0.90	0.95	0.95	0.95
MI	0.08	0.75	0.90	0.66	0.66	1.00	1.00	1.00	0.45	0.45
MN	0.15	0.90	0.90	0.85	0.85	1.00	1.00	1.00	0.40	0.40
MS	0.10	0.75	0.60	0.65	0.65	0.90	0.90	0.95	0.85	0.85
МО	0.10	0.60	0.65	0.65	0.65	0.85	0.85	0.90	0.75	0.75
MT	0.01	0.85	0.75	0.80	0.80	1.00	1.00	1.00	0.90	0.90
NE	0.08	0.90	0.80	0.66	0.66	1.00	1.00	1.00	0.64	0.64

EXHIBIT 2-2
Fraction of Recoverable Manure, by Animal and by State (Top Ten Producing States Indicated by Bold Font)

State	Beef (Grazing)	Beef (Fattened)	Milk	Swine (Breeding)	Swine (Other)	Laying Hen/Pullet	Pullets (<3 mos.)	Broilers	Turkeys (slaughter)	Turkeys (breeding)
NV	0.05	0.85	0.80	0.85	0.85	0.90	0.90	0.90	0.65	0.65
NH	0.10	0.85	0.80	0.80	0.80	1.00	1.00	1.00	0.95	0.95
NJ	0.10	0.85	0.80	0.80	0.80	0.90	0.90	0.95	0.95	0.95
NM	0.00	0.80	0.85	0.85	0.90	0.90	0.90	0.90	0.65	0.65
NY	0.10	0.85	0.80	0.80	0.80	0.90	0.90	0.95	0.95	0.95
NC	0.00	0.75	0.59	0.90	0.90	1.00	1.00	1.00	0.99	0.99
ND	0.00	0.85	0.80	0.50	0.50	1.00	1.00	1.00	0.85	0.85
ОН	0.10	0.70	0.90	0.75	0.75	1.00	1.00	1.00	0.70	0.70
ОК	0.10	0.80	0.65	0.75	0.75	1.00	1.00	1.00	0.80	0.80
OR	0.05	0.85	0.60	0.85	0.85	0.90	0.90	0.90	0.65	0.65
PA	0.05	0.85	0.80	0.80	0.80	0.95	0.95	0.95	0.95	0.95
RI	0.10	0.85	0.80	0.80	0.80	0.90	0.90	0.95	0.95	0.95
SC	0.00	0.80	0.59	0.49	0.49	1.00	1.00	1.00	0.85	0.85
SD	0.10	0.75	0.80	0.70	0.70	0.95	0.95	0.95	0.80	0.80
TN	0.10	0.75	0.60	0.65	0.65	0.90	0.90	0.95	0.85	0.85
TX	0.05	0.85	0.75	1.00	1.00	1.00	1.00	1.00	1.00	0.80
UT	0.05	0.85	0.80	0.85	0.85	0.90	0.90	0.90	0.65	0.65
VT	0.20	0.90	0.90	0.80	0.80	0.90	0.90	0.95	0.95	0.95
VA	0.10	0.85	0.60	0.80	0.80	1.00	1.00	1.00	1.00	1.00
WA	0.05	0.85	0.80	0.85	0.85	0.80	0.80	0.80	0.65	0.65
wv	0.00	1.00	0.80	0.75	0.75	1.00	1.00	1.00	1.00	1.00
WI	0.08	0.70	0.90	0.66	0.66	1.00	1.00	1.00	0.70	0.70
WY	0.05	0.80	0.80	0.75	0.75	0.95	0.95	0.95	0.75	0.75

Source: Recoverable fractions are from Lander et al. (1998). Top producing states were identified through the 1992 Census of A griculture (USDC/Census Bureau, 1994).

Exhibit 2-3 lists the amount of recoverable manure and recoverable nutrients (nitrogen and phosphorus) generated by individual animal sectors (beef, dairy, swine, and poultry operations) throughout the U.S. in 1997. Nationwide, approximately 16 percent of beef manure was recoverable, accounting for 22 percent of total recoverable livestock manure (dry-state). Approximately 76 percent of dairy manure was recoverable, translating to 37 percent of recoverable livestock manure. About 92 percent of swine manure was recoverable, accounting for 13 percent of total recoverable livestock manure. Nationwide, 98 percent of poultry manure was recoverable, representing approximately 27 percent of recoverable livestock manure. These quantities reflect the most recent estimates by USDA of manure generation from livestock and poultry operations, using an approach developed by Lander et al. (1998). The benefits analysis contains additional information on manure production.

EXHIBIT 2-3
Estimated Recoverable Manure and Manure Nutrients Generated by Sector

		1997 Manure Production						
Animal Group	Recoverable Manure (million lbs)	Percent of Total Manure Production That Is Recoverable	Recoverable Nitrogen (1,000 lbs)	Recoverable Phosphorus (1,000 lbs)				
Beef	28,637	16%	484	340				
Dairy	47,476	76%	672	266				
Swine	17,120	92%	274	277				
Poultry - Total	34,979	98%	1,153	554				
Layers	7,101	98%	231	123				
Broilers	19,199	98%	616	255				
Turkeys	8,679	98%	306	175				
Total, all livestock	128,212	44%	2,583	1,437				

Calculated by USDA/NRCS based on 1997 Census of Agriculture (USDA/NASS, 1999) using procedures in Lander et al. 1998. Numbers are "dry state" (wet basis, adjusted for water content).

Recoverable Nitrogen

Poultry manure has the highest amount of recoverable nitrogen (58 percent), making up 45 percent of all recoverable nitrogen for the sectors under consideration. Dairy manure has the next highest amount of recoverable nitrogen (30 percent), accounting for 26 percent of all recoverable nitrogen for the sectors under consideration. Manure from pork operations had the third highest amount of recoverable nitrogen (23 percent), accounting for 11 percent of the total for these sectors. Beef manure had the lowest ratio of recoverable nitrogen (6 percent), but due to volume this source accounted for 19 percent of the total for all sectors (Lander et al., 1998).

Recoverable Phosphorus

Poultry manure also had the highest amount of recoverable phosphorus (83 percent), making up 39 percent of all recoverable phosphorus. Swine manure had the second highest amount of recoverable phosphorus (78 percent), accounting for 19 percent of the recoverable phosphorus

from the sectors considered. Manure from dairy operations ranked third for recoverable phosphorus (66 percent) and generated 19 percent of the recoverable phosphorus from all four sectors. As with nitrogen, beef manure also had the lowest ratio of recoverable phosphorus (14 percent), but due to volume this source ranked second for all sectors with 24 percent (Lander et al., 1998).

2.2 POLLUTANTS OF CONCERN

The primary pollutants associated with animal waste are nutrients (particularly nitrogen and phosphorus), ammonia,³ pathogens, and organic matter. Animal waste is also a source of salts and trace elements, and to a lesser extent, antibiotics, pesticides, and hormones. The actual composition of manure depends on the animal species, size, maturity, and health, as well as on the composition (e.g., protein content) of animal feed (Phillips et al., 1992). After waste has been excreted, it may be altered further by the bedding and waste feed, and may be diluted with water (Loehr, 1972; USDA, 1992).

The following sections describe the characteristics of each main group of AFO pollutants. The estimates of manure pollutant production are based on average values reported in the scientific literature and compiled by the American Society of Agricultural Engineers (ASAE, 1999), USDA/NRCS (1996), and USDA/ARS (1998).

2.2.1 Nutrients

The three primary nutrients in manure are nitrogen, phosphorus, and potassium. Much of the past research on animal manure has focused on these constituents, given their importance as cropland fertilizers. The following discussions provide more detail on nitrogen and phosphorus characteristics and concentrations in manure. Scientific literature and policy statements commonly cite these two nutrients as key sources of water quality impairments. In the central United States, a 1995 estimate notes that 37 percent of all nitrogen and 65 percent of all phosphorus inputs to watersheds come from manure (USFWS, 2000). Actual or anticipated levels of potassium in ground water and surface water are unlikely to pose hazards to human health or aquatic life (Wetzel, 1983). Potassium does contribute to salinity, however, and applications of high salinity manure are likely to decrease the fertility of the soil.

Exhibit 2-4 presents the amounts of total Kjeldahl nitrogen,⁴ total phosphorus, orthophosphorus, and potassium generated per 1,000 pounds live animal weight per day (ASAE, 1999). For comparison, Exhibit 2-4 presents similar information for humans. The figures illustrate that perpound nutrient output varies among animal types and is much higher for animals than humans.

³Ammonia is also a nutrient but is listed separately here because it exhibits additional environmental effects, such as aquatic toxicity and direct dissolved oxygen demand.

⁴Total Kjeldahl nitrogen is the sum of organic nitrogen in the trinegative oxidation state and ammonia.

EXHIBIT 2-4
Primary Nutrients in Both Livestock and Human Manures

	Animal Group									
Nutrient	Swine	Swine Layer		Broiler Turkey		Dairy	Human			
Mass of animal (lbs.)	135	4.0	2.0	15	800	1,400	150			
	Pounds per 1,000 pounds live animal weight per day									
Nitrogen (Total Kjeldahl)	0.52	0.84	1.1	0.62	0.34	0.45	0.20			
Phosphorus (Total)	0.18	0.30	0.30	0.23	0.092	0.094	0.02			
Orthophosphorus	0.12	0.09	n/a	n/a	0.03	0.061	n/a			
Potassium	0.29	0.30	0.40	0.24	0.21	0.29	0.07			

Sources: Livestock data are "as excreted" and are from ASAE (1999); human waste data are "as excreted" and are from USDA/NRCS (1996).

Values rounded to two significant figures.

n/a = not available

Nitrogen Compounds

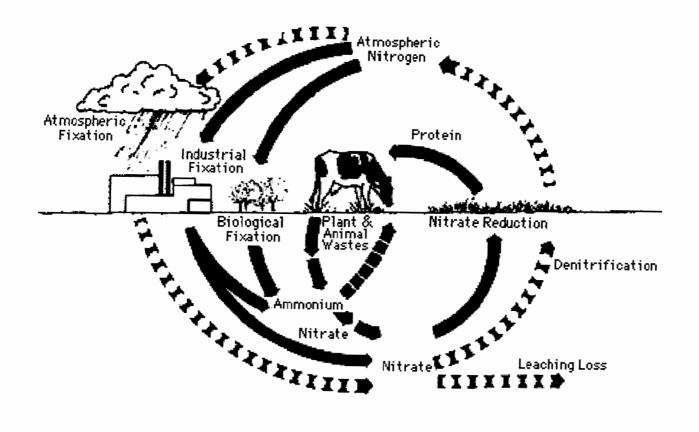
Nitrogen (N) is an essential nutrient required by all living organisms. Nitrogen occurs in the environment in gaseous forms (elemental nitrogen, N₂; nitrogen oxide compounds, N₂O and NO_x; and ammonia, NH₃); water soluble forms (ammonia, NH₃; ammonium, NH₄⁺; nitrite, NO₂⁻; and nitrate, NO₃⁻); and as organic nitrogen, bound up in the proteins of living organisms and decaying organic matter (Brady, 1990). The transformation of the different forms of nitrogen among land, water, air, and living organisms is known as the nitrogen cycle (Exhibit 2-5).

Nitrogen in fresh manure exists primarily in the organic and ammonium forms (NCAES, 1982). Sixty to 90 percent of total nitrogen in fresh manure is in the organic form. Organic nitrogen in the solid content of animal feces is mostly in the form of complex molecules associated with digested food, while organic nitrogen in urine is mostly in the form of urea ((NH₂)₂CO) (USDA, 1992). In organic form, nitrogen is unavailable to plants. However, via microbial processes, organic nitrogen is transformed to ammonium (NH₄⁺) and nitrate (NO₃⁻) forms, which are bioavailable and therefore have fertilizer value.

Under aerobic conditions, ammonia can oxidize to nitrites and nitrates. Subsequent anaerobic conditions can result in denitrification (transformation of nitrates/nitrites to gaseous nitrogen forms). Overall, depending on the animal type and specific waste management practices, between 30 and 90 percent of nitrogen excreted in manure can be lost before use as a fertilizer (Vanderholm, 1975).

⁵In an anaerobic lagoon, the organic fraction is about 20 to 30 percent of total nitrogen (USDA, 1992).

EXHIBIT 2-5
The Nitrogen Cycle



Source: O'Leary et al., 1997.

Phosphorus Compounds

Phosphorus exists in solid and dissolved phases, in both organic and inorganic forms. Like nitrogen, the various forms of phosphorus are subject to transformation (Exhibit 2-6). Dissolved phosphorus in the soil environment consists of orthophosphates (PO₄⁻³, HPO₄⁻², or H₂PO₄⁻), inorganic polyphosphates, and organic phosphorus (Poultry Water Quality Consortium, 1998). Solid phosphorus exists as organic phosphorus in dead and living materials; mineral phosphorus in soil components; adsorbed phosphorus on soil particles; and precipitate phosphorus, which forms upon reaction with soil cations such as iron, aluminum, and calcium (Poultry Water Quality Consortium, 1998). Orthophosphate species, both soluble and attached, are the predominant forms of phosphorus in the natural environment (Bodek et al., 1988). Soluble (available or dissolved) phosphorus generally accounts for a small percentage of total soil phosphorus. However, soils saturated with phosphorus can have significant occurrences of phosphorus leaching. Soluble phosphorus is the form used by plants and is subject to leaching. About 73 percent of the phosphorus in most types of fresh livestock waste is in the organic form (USDA, 1992). As animal waste ages, the organic phosphorus mineralizes to inorganic phosphate compounds and becomes available to plants.

2.2.2 Ammonia

Ammonium (NH_4^+) is produced when microorganisms break down organic nitrogen products (e.g., urea and proteins in manure). This decomposition can occur in either aerobic or anaerobic environments. In solution, ammonium enters into an equilibrium reaction with ammonia (NH_3) , as shown in the following equation:

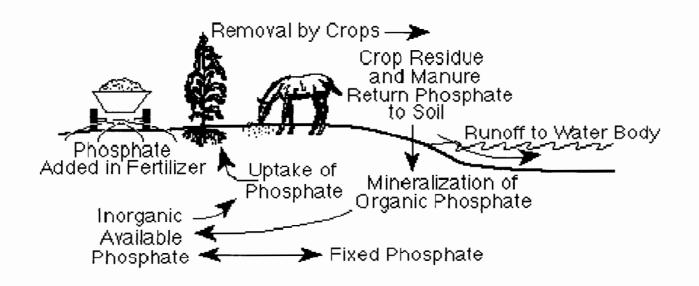
$$NH_4^+ = NH_3 + H^+$$

Up to 50 percent or more of the nitrogen in fresh manure may be in the ammonia form or converted to ammonia relatively quickly once manure is excreted (Vanderholm, 1975). Ammonia is very volatile, and much of it is emitted as a gas, although it may also be absorbed by or react with other substances.

Higher pH levels (lower H⁺ concentrations) favor the formation of ammonia, while lower pH levels (higher H⁺ concentrations) favor the formation of ammonium. The ammonia form is subject to volatilization.

The ammonia content of fresh manure varies among animal species and changes as the manure ages. Ammonia content may increase as organic matter breaks down; it may decrease when volatilization occurs or when nitrate oxidizes to nitrite under aerobic conditions.

EXHIBIT 2-6 The Phosphorus Cycle



Source: Busman et al., 1997.

2.2.3 Pathogens

Both manure and animal carcasses can be sources of pathogens (disease-causing organisms) in the environment (Juranek, 1995). Livestock manure may contain bacteria, viruses, fungi, helminths, protozoa, and parasites, many of which are pathogenic (USDA, 1998; Jackson et al., 1987). For example, researchers have isolated pathogenic bacteria and viruses from feedlot wastes (Derbyshire et al., 1966; Hrubant, 1973; Derbyshire and Brown, 1978). In addition, USFWS (2000) has shown fields receiving animal waste applications to have elevated levels of fecal coliforms and fecal streptococci. Specifically, bacteria such as *Escherichia coli* O157:H7, *Salmonella* species, *Campylobacter jejuni, Listeria monocytogenes*, and *Leptospira* species are often found in livestock manure and have also been associated with waterborne disease. A recent study by the USDA revealed that about half the beef cattle presented for slaughter during July and August 1999 carried *Escherichia coli* O157:H7 (Elder et al., 2000). Also, protozoa, including *Cryptosporidium parvum* and *Giardia* species (such as *Giardia lamblia*), may occur in animal waste. *Cryptosporidium parvum* is associated with cows in particular; newborn dairy calves are especially vulnerable to infection and excrete large numbers of the infectious oocysts (USDA, 1998). Most pathogens are shed from host animals with active infections.

Presence of bacteria (and other pathogens) is often measured by the level of fecal coliforms, *Escherichia coli*, or enterococci in manure (Bouzaher et al., 1993). Use of indicator organisms such as these has limitations; specifically, that there are no established relationships between fecal coliform and pathogen contamination. However, indicators are still used because specific pathogen testing protocols are too time consuming, expensive, and/or insensitive to be used for monitoring purposes (Shelton, 2000). Exhibit 2-7 lists the number of total coliform bacteria, fecal coliform bacteria, and fecal streptococcus bacteria per cubic foot of manure for swine, poultry, beef, and dairy animals (ASAE, 1999).

EXHIBIT 2-7
Coliform Bacteria in Manure (colonies per cubic foot of manure, as excreted)

Animal Group	Total Coliform Bacteria	Fecal Coliform Bacteria	Fecal Streptococcus Bacteria
Swine	1.6 x 10 ¹¹	5.9 x 10 ¹⁰	18 x 10 ¹¹
Poultry (layers)	4.7 x 10 ¹¹	3.2 x 10 ¹⁰	0.69 x 10 ¹¹
Beef	3.2 x 10 ¹¹	14 x 10 ¹⁰	1.5 x 10 ¹¹
Dairy	36 x 10 ¹¹	5.2 x 10 ¹⁰	3.0 x 10 ¹¹

Source: ASAE (1999).

Values rounded to two significant figures.

2.2.4 Organic Matter

Livestock manures contain many carbon-based, biodegradable compounds. These compounds are of concern in surface water because dissolved oxygen is consumed as aquatic bacteria and other microorganisms decompose these compounds. This process reduces the amount of oxygen available for aquatic animals.

.. - .

The greater the manure's concentration of materials that can be readily decomposed, the greater the manure's oxygen demand. Two measures are often used to estimate oxygen demand. Biochemical oxygen demand (BOD) is an indirect measure of the concentration of biodegradable substances present in an aqueous solution. The ultimate BOD is the amount of oxygen required to completely degrade the waste biologically under aerobic conditions. BOD is often expressed as BOD₅. This measure refers to the amount of oxygen required by bacteria while decomposing organic matter under aerobic conditions over a five-day period at 20°C in a laboratory test. BOD₅ is expressed as the number of milligrams of oxygen required to support oxidation of the compounds in one liter of liquid waste. Alternatively, the chemical oxygen demand (COD) test uses a chemical oxidant. This test provides an approximation of the ultimate BOD and can be estimated more quickly than the five days required for the BOD₅ test. If the waste contains only readily available organic bacterial food and no toxic matter, the COD values correlate with BOD values obtained from the same wastes (Dunne and Leopold, 1978).

Exhibit 2-8 lists BOD₅ and COD estimates for manure generated by swine, poultry, beef, and dairy animals and, for comparison, provides values for domestic sewage. Reported BOD₅ values for various untreated animal manures range from 24,000 mg/L to 33,000 mg/L. COD values range from 25,000 mg/L to 260,000 mg/L. Dairy and beef cattle manure have BOD₅ and COD values of similar magnitude. By comparison, the BOD₅ value for raw domestic sewage ranges from 100 mg/L to 300 mg/L. Even after biological treatment in anaerobic lagoons, animal waste BOD₅ concentrations (200 mg/L to 3,800 mg/L) are much higher than those of municipal wastewater treated to the secondary level (about 20 mg/L) (USDA, 1992).

W aste	BOD _s (mg/L)	COD (mg/L)
Swine manure Untreated Anaerobic lagoon influent Anaerobic lagoon effluent	27,000 to 33,000 13,000 300 to 3,600	25,000 to 180,000 n/a n/a
Poultry manure Untreated (chicken) Anaerobic lagoon influent (poultry) Anaerobic lagoon effluent (poultry)	24,000 9,800 600 to 3,800	100,000 to 260,000 n/a n/a
Dairy cattle manure Untreated Anaerobic lagoon influent Anaerobic lagoon effluent	26,000 6,000 200 to 1,200	68,000 to 170,000 n/a n/a
Beef cattle manure Untreated Anaerobic lagoon influent Anaerobic lagoon effluent	28,000 6,700 200 to 2,500	73,000 to 260,000 n/a n/a
Domestic sewage Untreated After secondary treatment	100 to 300 20	400 to 600 n/a

Sources: Untreated values, except for beef manure BOD₅, are from NCAES (1982). The BOD₅ value for beef manure is from ASAE (1997). Lagoon influent and effluent concentrations are from USDA/NRCS (1996). Values rounded to two significant figures.

n/a = not available

2.2.5 Salts and Trace Elements

The salinity of animal manure is directly related to the presence of the nutrient potassium and dissolved mineral salts that pass through the animal. In particular, significant concentrations of soluble salts containing the cations sodium and potassium remain from undigested feed that passes unabsorbed through animals (NCAES, 1982). Other major cations contributing to salinity are calcium and magnesium; the major anions are chloride, sulfate, bicarbonate, carbonate, and nitrate (National Research Council, 1993). Salinity tends to increase as the volume of manure decreases during decomposition and evaporation (Gresham et al., 1990).

Trace elements in manure that are of environmental concern include arsenic, copper, selenium, zinc, cadmium, molybdenum, nickel, lead, iron, manganese, aluminum, and boron. Arsenic, copper, selenium, and zinc are often added to animal feed as growth stimulants or biocides (Sims, 1995). Trace elements may also end up in manure through use of pesticides, which farmers apply to livestock to suppress houseflies and other pests (USDA/ARS, 1998).

It is useful to compare trace element concentrations in manure to those in municipal sewage sludge, which is regulated by the EPA's Standards for the Use or Disposal of Sewage Sludge promulgated under the Clean Water Act and published in 40 CFR Part 503 (USEPA, 1993c). Regulated trace elements in sewage sludge include arsenic, cadmium, chromium, copper, lead,

mercury, molybdenum, nickel, selenium, and zinc. Sims (1995) has reported total concentrations of trace elements in animal manures as comparable to those in some municipal sludges, with typical values well below the maximum concentrations allowed by Part 503 for land-applied sewage sludge.

2.2.6 Antibiotics

A number of pharmacological agents, including antibiotics, are used in animal feeding operations and can appear in animal wastes. Some of these agents are used only therapeutically (e.g., to treat illness). Others are used both therapeutically and as feed additives to promote growth or to improve feed conversion efficiency. In 1991, farmers used an estimated 19 million pounds of antibiotics for disease prevention and growth promotion in animals. From 60 to 80 percent of animals receive antibiotics during their productive life span (Tetra Tech, 2000a). Use as feed additives accounts for most of the mass of antibiotics used in both the swine and poultry industries and accounts for the presence of antibiotics in the resulting manure. Although antibiotic residues in beef and dairy manure are also a concern, the EPA could not locate any literature on levels of antibiotics in manure. Estimated concentrations of the antibiotic chlortetracycline in the lagoon systems of a pork producer in Nebraska range from 150 to 300 mg/L; that producer currently uses 16 different antibiotics as feed and drinking water additives (USFWS, 2000).

2.2.7 Hormones

Hormones are the chemical messengers that carry instructions to target cells throughout the body and are normally produced by the body's endocrine glands. The target cells read and follow the hormones' instructions, sometimes building a protein or releasing another hormone. These actions lead to many bodily responses such as a faster heart beat or bone growth. Hormones include steroids (estrogen, progesterone, testosterone), peptides (antidiuretic hormone), polypeptides (insulin), amino acid derivatives (melatonin), and proteins (prolactin, growth hormone). Natural hormones are potent; only very small amounts are needed to cause an effect.

Specific hormones are administered to cattle to increase productivity in the beef and dairy industries, and several studies have shown that hormones are present in animal manures (Mulla, 1999). For example, poultry manure has been shown to contain about 30 ng/g of estrogen, and about the same levels of testosterone (Shore et al., 1995). Also, estrogen was found in concentrations up to 20 ng/L in runoff from fields fertilized with chicken manure (Shore et al., 1995).

2.2.8 Other Pollutants of Concern

AFOs can also be a source of gas emissions, particulates, and pesticides. A general overview of each group of pollutants follows:

• Gas emissions. The degradation of animal wastes by microorganisms produces a variety of gases. Sources of odor include animal confinement buildings, waste lagoons, and land application sites. In addition to ammonia, which was discussed

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earlier, three main gases generated from manure are carbon dioxide, methane, and hydrogen sulfide. Aerobic conditions yield mainly carbon dioxide, while anaerobic conditions generate both methane and carbon dioxide. Anaerobic conditions, which dominate in typical, unaerated animal waste lagoons, also generate hydrogen sulfide and over 150 other odorous compounds, including volatile fatty acids, phenols, mercaptans, aromatics, sulfides, and various esters, carbonyls, and amines (O'Neill and Phillips, 1992; USDA, 1992; Bouzaher et al., 1993).

- Particulates. Sources of particulate emissions from AFOs may include dried manure, feed, epithelial cells, hair, and feathers. The airborne particles make up an organic dust, which includes endotoxin (the toxic protoplasm liberated when a microorganism dies and disintegrates), adsorbed gases, and possibly steroids. At least 50 percent of dust emissions from swine operations may be respirable (Thu, 1995).
- Pesticides. Pesticides are used in animal feeding operations and can appear in animal
 wastes. Farmers may use pesticides on crops grown for animal consumption or
 directly in animal housing areas to control parasites (among other reasons). However,
 little information is available regarding the concentrations of pesticides in animal
 wastes or on their bioavailability in waste-amended soils.

2.3 TRANSPORT OF MANURE POLLUTANTS TO SURFACE WATER

Pollutants found in animal manures can reach surface water by several mechanisms. These can be categorized as either surface discharges or other discharges. Surface discharges can result from runoff, erosion, spills, and dry-weather discharges. In surface discharges, the pollutant travels overland or through drain tiles with surface inlets to a nearby stream, river, or lake. Direct contact between confined animals and surface waters is another means of surface discharge. For other types of discharges, the pollutant travels via another environmental medium (ground water or air) to surface water.

2.3.1 Surface Discharges

Runoff

Feedlot runoff contains extremely large loads of nutrients and oxygen-demanding substances, which can severely degrade surface water quality (Mulla, 1999). Water that falls on man-made surfaces or soil and fails to be absorbed will flow across the surface. This process is called runoff. Surface discharges of manure pollutants can originate from feedlots and from overland runoff at land application sites. Runoff is especially likely at open-air feedlots, when rainfall occurs soon after application, and when farmers over-apply or misapply manure. For example, experiments show that for all animal wastes, the application rate has a significant effect on the runoff concentration (Daniel et al., 1995). Other factors that promote runoff to surface waters are steep land slope, high rainfall, low soil porosity or permeability, and close proximity to surface waters. In addition, manure applied to saturated or frozen soils is more likely to run off the soil surface (Mulla, 1999). Runoff of pollutants dissolved into rainwater is a significant transport

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mechanism for water soluble pollutants, including nitrate, nitrite, and organic forms of phosphorus.

Runoff of manure pollutants has been identified as a factor in a number of documented impacts from AFOs. For example, in 1994, an environmental advocacy group noted multiple runoff problems for a swine operation in Minnesota (Clean Water Action Alliance, 1998), and in 1996, the State of Ohio identified runoff from manure spread on land at several Ohio operations that were feeding swine and chicken (Ohio Department of Natural Resources, 1997). More discussion of runoff and its impacts on the environment and human health appears later in this document.

Erosion

In addition to runoff, surface discharges can occur by erosion, in which the soil surface is worn away by the action of water or wind. Erosion is a significant transport mechanism for landapplied pollutants, such as phosphorus, that are strongly sorbed to soils (Gerritse, 1977).

The USDA Natural Resources Conservation Service (NRCS) reviewed the manure production in a watershed in South Carolina. Agricultural activities in the project area are a major influence on the streams and ponds in the watershed and contribute to nutrient-related water quality problems in the headwaters of Lake Murray. NRCS found that bacteria, nutrients, and sediment from soil erosion are the primary contaminants affecting the waters in this watershed. The NRCS has calculated that soil erosion, occurring on over 13,000 acres of cropland in the watershed, ranges from 9.6 to 41.5 tons per acre per year (USEPA, 1997b).

Spills and Dry-Weather Discharges

Surface discharges can occur through spills or other discharges from lagoons. Catastrophic spills from large manure storage facilities can occur primarily through overflow following large storms or by intentional releases (Mulla et al., 1999). Other causes of spills include pump failures, malfunctions of manure irrigation guns, and breakage of pipes or retaining walls. Manure entering tile drains has a direct route to surface water. (Tile drains are a network of pipes buried in fields below the root zone of plants to remove subsurface drainage water from the root zone to a stream, drainage ditch, or evaporation pond.) In addition, spills can occur as a result of washouts from floodwaters when lagoons are sited on floodplains. There are also indications that discharges from siphoning lagoons occur deliberately as a means to reduce the volume in overfull lagoons (Clean Water Action Alliance, 1998). An independent review of Indiana Department of Environmental Management records indicated that two common causes of waste releases in that state were intentional discharges and accidental discharges resulting from lack of operator knowledge (Hoosier Environmental Council, 1997).

Localities have identified numerous such discharges. The Ohio Department of Natural Resources (ODNR) documented chicken manure traveling through tile drains into a nearby stream in several instances occurring in 1994, 1995, and 1996 (ODNR, 1997). In 1995, a discharge of 25 million gallons of manure from swine farms in North Carolina was documented (Meadows, 1995; NRDC, 1995; Warrick, 1995b). Subsequent discharges of hundreds of

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thousands of gallons of manure were documented from swine operations in Iowa (1996), Illinois (1997), and Minnesota (1997) (IDNR, 1998; Illinois Stewardship Alliance, 1997; Macomb Journal, 1999; Clean Water Action Alliance, 1998). Between 1994 and 1996, half a dozen discharges from poultry operations in Ohio resulted when manure entered drain tiles (ODNR, 1997). In 1996, more than 40 animal waste spills occurred in Iowa, Minnesota, and Missouri alone (U.S. Senate, 1997). In 1998, a dairy feedlot in Minnesota discharged 125,000 gallons of manure (Clean Water Action Alliance, 1998). Acute discharges of this kind frequently result in dramatic fish kills. For example, fish kills were reported as a result of the North Carolina, Iowa, Minnesota, and Missouri discharges mentioned above.

Direct Contact between Confined Animals and Surface Water

Finally, surface discharges can occur as a result of direct contact between confined animals and the rivers or ponds that are located within their reach. Historically, people located their farms near waterways for both water access by animals and discharge of wastes. Certain animals, particularly cattle, wade into the waterbody, linger to drink, and often urinate and defecate in the water. This practice is now restricted for CAFOs; however, enforcement actions are the primary means for reducing direct access, as described below (McFall, 2000).

In traditional farm production regions of the Midwest and Northeast, dairy barns and feedlots are often in close proximity to streams or other water sources. This close proximity to streams was formerly necessary in order to provide drinking water for the dairy cattle, to cool the animals in hot weather via direct access, and to cool the milk prior to the widespread use of refrigeration. For CAFO-size facilities, this practice is now replaced with more efficient means of providing drinking water for the dairy herd. In addition, the use of freestall barns and modern milking centers minimizes the exposure of dairy cattle to the environment. For example, in New York direct access of animals to surface water is more of a problem for the smaller, traditional dairy farms that use older methods of housing animals. However, at these smaller facilities, direct access to surface water has relatively lower impact on surface water compared with impacts associated with silage leachate and milkhouse waste (Dimura, 2000).

In the arid West, feedlots are typically located near waterbodies to allow for cheap and easy stock watering. Many existing lots were configured to allow the animals direct access to the water. The direct deposition of manure and urine contributes greatly to water quality problems. Environmental problems associated with allowing farm animals access to waters that are adjacent to the production area are well documented in the literature. EPA Region X staff have documented dramatically elevated levels of *Escherichia coli* in rivers downstream of AFOs with direct access to surface water. Recent enforcement actions against direct access facilities have resulted in the assessment of tens of thousands of dollars in civil penalties (McFall, 2000).

2.3.2 Other Discharges to Surface Waters

Leaching to Ground Water

Leaching of land-applied pollutants is a significant transport mechanism for water soluble pollutants. In addition, leaking lagoons are a source of manure pollutants in ground water.

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Although manure solids purportedly "self-seal" lagoons to prevent ground water contamination, some studies have shown otherwise. A study for the Iowa legislature published in 1999 indicates that leaking is part of lagoon design standards and that all lagoons should be expected to leak (Iowa State University, 1999). A survey of swine and poultry lagoons in the Carolinas found that nearly two-thirds of the 36 lagoons sampled had leaked into the ground water (Meadows, 1995). Even clay-lined lagoons have the potential to leak, since they can crack or break as they age, and can be susceptible to burrowing worms. In a three-year study of clay-lined swine lagoons on the Delmarva Peninsula, researchers found that leachate from lagoons located in well-drained loamy sand had a severe impact on ground water quality (Ritter and Chirnside, 1990).

Pollutant transport to ground water is also greater in areas with high soil permeability and shallow water tables. Percolating water can transport pollutants to ground water, as well as to surface waters via interflow. Contaminated ground water can deliver pollutants to surface waters through hydrologic connections. Nationally, about 40 percent of the average annual stream flow is from ground water (USEPA, 1993b). In the Chesapeake Bay watershed, the USGS estimates that about half of the nitrogen loads from all sources to nontidal streams and rivers originate from ground water (ASCE, 1998).

Understanding the connection between ground water and surface water is important when developing surface water protection strategies, because ground water moves much more slowly than surface water. For example, ground water in the Chesapeake Bay region takes an average of 10 to 20 years to reach the Bay; thus, it may take several decades to realize the full effect of pollutant additions or reductions (ASCE, 1998).

Discharge to the Air and Subsequent Deposition

Atmospheric deposition can be a significant mechanism of transport to surface waters, as nitrogen emissions to air can return to terrestrial or aquatic environments in dry form or dissolved in precipitation (Agricultural Animal Waste Task Force, 1996). Discharges to air can occur as a result of volatilization of pollutants already present in the manure, and of pollutants generated as the manure decomposes. Ammonia is very volatile and can have significant impacts on water quality through atmospheric deposition (Aneja et al., 1998). Ammonia losses from animal feeding operations can be considerable, arising from manure piles, storage lagoons, and land application fields. Other ways that manure pollutants can enter the air are from spray application methods for land applying manure and from particulates wind-borne in dust.

The degree of volatilization of manure pollutants is dependent on the manure management system. For example, losses are greater when manure remains on the land surface rather than being incorporated into the soil and are particularly high when farmers perform spray application. Environmental conditions such as soil acidity and moisture content also affect the extent of volatilization. Losses are reduced by the presence of growing plants (Follett, 1995).

Once airborne, pollutants can find their way into nearby streams, rivers, and lakes. The 1998 *National Water Quality Inventory* indicates that atmospheric deposition is the third largest cause of water quality impairment for estuaries and the fifth largest cause of water quality impairment for lakes, ponds, and reservoirs (USEPA, 2000a).

2.3.3 Pollutant-specific Transport

Nitrogen Compounds

Livestock waste can contribute up to 37 percent of total nitrogen loads to surface water (Mulla, 1999). Nitrogen compounds and nitrates in manure can reach surface water through several pathways. As suggested by Follett (1995), agricultural nitrate contributions to surface water are primarily from ground water connections and other subsurface flows. Although potentially less significant, overland runoff can also carry nitrate to surface waters. A recent Iowa investigation of chemical and microbial contamination near large-scale swine operations demonstrated the presence of nitrate and nitrite not only in manure lagoons used to store swine waste before it is land applied, but also in drainage ditches, agricultural drainage wells, tile line inlets and outlets, and an adjacent river (CDCP, 1998).

Studies of small geographical areas have revealed evidence of nitrate contamination in ground water. As of 1988, 40 percent of wells in the Chino Basin, California, had nitrate levels in excess of the MCL; USEPA (1993b) identified dairy operations as the major source of contamination. This presents potentially widespread impacts, since water from the Chino Basin is used to recharge the primary source of drinking water for residents of heavily populated Orange County. On the Delmarva peninsula, in Maryland, where poultry production is dominant, over 15 percent of wells were found to have nitrate levels exceeding the MCL. Wells located close to chicken houses contained the highest median nitrate concentrations (Ritter et al., 1989). Measured nitrate levels in ground water beneath Delaware poultry houses are as high as 100 mg/L (Ritter et al., 1989).

Elevated nitrate levels can also exist in surface waters, although these impacts are typically less severe than ground water impacts. In a historical assessment, USGS (1997) found that nitrate levels in streams in agricultural areas were elevated compared to undeveloped areas. Nevertheless, the in-stream nitrate concentrations were generally less than those for ground water in similar locations, and the drinking water MCL was rarely exceeded. The primary exception to this pattern was in the Midwest, where poorly drained soils restrict water percolation and artificial drainage provides a quick path for nutrient-rich runoff to reach streams (USGS, 1997).

When farmers apply manure to land as fertilizer, risk of nitrate pollution generally increases at higher rates of nitrogen application. Even when farmers land apply manure at agronomic rates, nitrogen transport to surface water and ground water can still occur for the following reasons: (1) nitrate is extremely mobile and may move below the plant root zone before being taken up; (2) ammonia may volatilize and be redeposited in surface water; (3) the waste may be unevenly distributed, resulting in local "hot spots"; (4) it may be difficult to obtain a representative sample of the waste to determine the amount of mineralized (plant-available) nitrogen; (5) there are uncertainties about the estimated rate of nitrogen mineralization in the applied waste; (6) transport is affected by the manure application method (e.g., drip irrigation, spray irrigation, knifing, etc.); and (7) transport is affected by uncontrollable environmental factors such as rainfall and other local conditions (Follett, 1995).

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Phosphorus Compounds

Phosphorus can reach surface waters via discharges directly into surface water and runoff of manure to surface water from feedlots, and via runoff and erosion from land application sites. The organic phosphorus compounds in manure are generally water soluble and subject to leaching and dissolution in runoff (Gerritse, 1977). Once in receiving waters, these compounds can undergo transformation and become available to aquatic plants. Overall, land-applied phosphorus is less mobile than nitrogen, since the mineralized (inorganic phosphate) form is easily adsorbed to soil particles. A report by the Agricultural Research Service noted that phosphorus bound to eroded sediment particles makes up 60 to 90 percent of phosphorus transported in surface runoff from cultivated land (USDA/ARS, 1999). For this reason, most agricultural phosphorus control measures have focused on soil erosion control to limit transport of particulate phosphorus. However, soils do not have infinite phosphate adsorption capacity, and dissolved inorganic phosphates can still enter waterways via runoff even if soil erosion is controlled (National Research Council, 1993).

Livestock waste can contribute up to 65 percent of total phosphorus loads in surface waters (Mulla, 1999). Animal wastes typically have lower N:P ratios than crop N:P requirements, such that application of manure at a nitrogen-based agronomic rate can result in application of phosphorus at several times the agronomic rate (Sims, 1995). Summaries of soil test data in the United States confirm that many soils in areas dominated by animal-based agriculture have excessive levels of phosphorus (Sims, 1995). Research also indicates that there is a potential for phosphorus to leach into ground water through sandy soils with already high phosphorus content (Citizens *Pfiesteria* Action Commission, 1997).

Ammonia

Ammonia can reach surface waters in a number of ways, including discharge directly to surface waters, leaching, dissolution in surface runoff, erosion, and atmospheric deposition. Leaching and runoff are generally not significant transport mechanisms for ammonia compounds in landapplied manure, because ammonium can be sorbed to soils (particularly those with high cation exchange capacity), incorporated (fixed) into clay or other soil complexes, or transformed into organic form by soil microbes (Follett, 1995). However, in these forms, erosion can transport nitrogen to surface waters. A recent Iowa investigation of chemical and microbial contamination near large-scale swine operations demonstrated the presence of ammonia not only in manure lagoons used to store swine waste before it is land applied, but also in drainage ditches, agricultural drainage wells, tile line inlets and outlets, and an adjacent river (CDCP, 1998).

Ammonia losses from animal feeding operations to the air and subsequent deposition to surface waters can be considerable, arising from sources such as manure piles, storage lagoons, and land application fields. For example, in North Carolina, animal agriculture is responsible for over 90 percent of all ammonia emissions (Aneja et al., 1998). Ammonia composes more than 40 percent of the total estimated nitrogen emissions from all sources (Aneja et al., 1998). Furthermore, data from Sampson County, North Carolina, indicate that ammonia levels in rain have increased with increases in the size of the pork industry. Levels more than doubled between 1985 and 1995 (Aneja et al., 1998). Based on EPA estimates, swine operations in eastern North

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Carolina were responsible for emissions of 135 million pounds of nitrogen per year as of 1995. If deposited in a single basin, this would result in nitrogen loadings of almost 2.1 million pounds of nitrogen per year (Nowlin et al., 1997).

Pathogens

Sources of pathogen contamination from AFOs include surface discharges and lagoon leachate. Surface runoff from land application fields can be a source of pathogen contamination, particularly if a rainfall event occurs soon after application or if the land is frozen or snow-covered (Mulla, 1999). Researchers have reported concentrations of bacteria in runoff water from fields treated with poultry litter at several orders of magnitude above contact standards (Giddens and Barnett, 1980; Coyne and Blevins, 1995).

A recent Iowa investigation of chemical and microbial contamination near large-scale swine operations demonstrated the presence of pathogens not only in manure lagoons used to store swine waste before it is land applied, but also in drainage ditches, agricultural drainage wells, tile line inlets and outlets, and an adjacent river (CDCP, 1998). Also, studies have reported that lands receiving fresh manure application can be the source of up to 80 percent of the fecal bacteria in surface waters (Mulla, 1999). Similarly, both *Cryptosporidium parvum* and *Giardia* species have also been found in over 80 percent of 66 surface water sites tested (LeChevallier et al., 1991). Since these protozoa do not multiply outside of the host, livestock animals are one potential source of this contamination. The bacterium *Erysipelothrix* spp., primarily a swine pathogen, has been isolated from many fish and avian species (USFWS, 2000).

High levels of indicator bacteria in surface water near CAFOs have been documented. For instance, Zirbser (1998) documented a report of fecal coliform counts of 3,000/100 ml and fecal streptococci counts over 30,000/100 ml downstream from a swine waste lagoon site. (No sampling was performed upstream of the lagoon site.) Fecal coliform pollution from treated and partially treated sewage and storm water runoff is often cited in beach closures and shellfish restrictions.

The natural filtering and adsorption action of soils typically causes a majority of the microorganisms in land-applied manure to be stranded at the soil surface (Crane et al., 1980). This phenomenon helps protect underlying ground water but increases the likelihood of runoff losses to surface waters. Pathogens discharged to the water column can subsequently adsorb to sediments, presenting a long-term health hazard. Benthic sediments harbor significantly higher concentrations of bacteria than the overlying water column (Mulla, 1999). When the bottom stream is disturbed, as when animals have direct access to a stream, the sediment releases bacteria back into the water column (Sherer et al., 1988, 1992).

While surface waters are typically more prone to pathogen contamination than ground waters, subsurface flows may also be a mechanism for pathogen transport depending on weather, site, and operating conditions. Ground waters in areas of sandy soils, limestone formations, or sinkholes are particularly vulnerable. For example, the bacteria *Clostridium perfringens* was detected in the ground water below plots of land treated with swine manure, and fecal coliform has been detected in ground water beneath soil amended with poultry manure (Mulla, 1999). In

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1998, Campylobacter jejuni was isolated from ground water, and some of the strains were the same type as those from a dairy farm in the same hydrologic area (Stanley et al., 1998).

There are other accounts of high levels of micoorganisms in ground water near feedlots. In cow pasture areas of Door County, Wisconsin, where a thin topsoil layer is underlain by fractured limestone bedrock, ground water wells have commonly been shut down due to high bacteria levels (Behm, 1989). For example, a well at one rural household produced brown, manure-laden water (Behm, 1989). Private wells are more prone to contamination than public wells, since they tend to be shallower and therefore more susceptible to contaminants leaching from the surface. In a survey of drinking water standard violations in six states over a four-year period, the U.S. General Accounting Office (USGAO, 1997) found that bacterial standard violations occurred in 3 to 6 percent of community water systems each year.⁶ By contrast, USGAO reported that some bacterial contamination occurred in 15 to 42 percent of private wells, according to statistically representative assessments performed by others.⁷

Several factors affect the likelihood of disease transmission by pathogens in animal manure, including pathogen survivability in the environment. For example, *Salmonella* can survive in the environment for nine months or more, providing for increased dissemination potential (USFWS, 2000); and *Campylobacter* can remain dormant, making water an important vehicle for campylobacteriosis (Altekruse, 1998). Recent studies are better characterizing the survivability and transport of pathogens in manure once it has been land applied. Several researchers (Dazzo et al., Himathongkham et al., 1999; Kudva et al., 1998; Maule, 1999; Van Donsel et al., 1967) found that soil type, manure application rate, temperature, moisture level, aeration, soil pH, and the amount of time that manure is held before it is applied to pastureland are dominating factors in bacteria survival.

Experiments on land-applied poultry manure (Crane et al., 1980) indicated that the population of fecal organisms decreases rapidly as manure is heated, dried, and exposed to sunlight on the soil surface. However, regrowth of fecal organisms also occurred in these experiments. More recent research indicated that pathogens can survive in manure for 30 days or more (Himathongkham et al., 1999; Kudva et al., 1998; Maule, 1999). Kudva found that *Escherichia coli* survived for 47 days in aerated cattle manure piles that were exposed to outdoor weather; drying the manure reduced the number of viable pathogens. Stehman (2000) also notes that *Escherichia coli* O157:H7, *Cryptosporidium parvum*, and *Giardia* can survive and remain infectious in surface waters for a month or more.

The continued application of waste on a particular area could lead to extended pathogen survival and buildup (Dazzo et al., 1973). Additionally, repeated applications and/or high application rates increase the likelihood of runoff to surface water and transport to ground water.

⁶GAO reviewed compliance data from 1993 through 1996, from more than 17,000 community water systems, in California, Illinois, Nebraska, New Hampshire, North Carolina, and Wisconsin.

⁷The 15 percent figure is from a 1996 study of Nebraska wells by the Nebraska Department of Health and University of Nebraska; the 42 percent figure is from the EPA National Statistical Assessment of Rural Water Conditions (1984).

Organic Matter

Discharge and runoff of manure from feedlots cause large loadings of organic matter to surface waters. There have been numerous incidents of discharges from AFOs nationwide directly to surface waters (see Chapter 4). Discharges can also originate from land application sites when farmers over-apply or misapply manure. Even if farmers apply manure such that there is not a concentrated discharge, organic matter will be present in runoff from land application sites. As shown by Daniel et al. (1995), runoff of organic matter increases as application rate increases. For example, Daniel et al. (1995) reported that when the swine manure slurry application rate increased from 193 lb N/acre to 387 lb N/acre, COD levels in runoff (generated from a rainfall intensity of 2 inches/hour) increased from 282 mg/L to 504 mg/L. By comparison, runoff from a control plot yielded 78 mg/L COD.

Salts and Trace Elements

Salts can reach surface waters via discharges from feedlots and runoff from land application sites. Salts can also leach into ground water and subsequently reach surface water. Trace elements can also be transported by these mechanisms. A recent Iowa investigation showed that trace elements were present not only in manure lagoons used to store swine waste before land application, but also in drainage ditches, agricultural drainage wells, tile line inlets and outlets, and an adjacent river (CDCP, 1998). Selenium concentrations have been detected in swine manure lagoons at up to 6 μ g/L, copper has been detected in liquid swine manure prior to land application at 15 mg/L, and zinc has been detected in soils that receive applications of cattle manure at levels up to 9.5 mg/kg in the upper 60 centimeters of soil (USFWS, 2000).

Antibiotics

Little information is available regarding the fate and transport properties of antibiotics, or the potential releases from animal waste compared to other sources such as municipal and industrial wastewaters, septic tank leachate, runoff from land-applied sewage sludge, crop runoff, and urban runoff. However, it is known that the primary mechanisms of eliminating antibiotics from livestock are through urine and bile. Also, essentially all of an antibiotic administered to an animal is eventually excreted, whether unchanged or in metabolite form (Tetra Tech, 2000a).

Although the presence of excreted antibiotics themselves may be of concern, the development of antibiotic-resistant pathogens due to exposure to environmental levels of antibiotics is generally of greater concern. The risk for development of antibiotic-resistant pathogens from this exposure is unknown.

⁸In a series of experiments, Edwards and Daniel (1992b, 1993a,b, as reported by Daniel et al., 1995) measured runoff from fescue grass plots treated with poultry litter, poultry manure slurry, and swine manure slurry to determine how runoff quality is impacted by application rate and rain intensity. They found that for all wastes, the application rate had a significant effect on the runoff concentration and mass loss of COD (as well as other constituents).

⁹EPA assumes that 175 lb N/acre is a typical requirement for a fescue crop in Arkansas, based on information from U.S. Department of Agriculture extension agents (Tetra Tech, 2000b).

Hormones

Hormones can reach surface waters through the same routes as other manure pollutants, including runoff and erosion as well as direct contact of animals with the water. Considering specific hormones used, however, estrogen is more likely to be lost by runoff than leaching, while testosterone is lost mainly through leaching (Shore et al., 1995).

Several sites have documented the presence of hormones in runoff and surface waters. For example, runoff from a field receiving poultry litter was found to contain estrogen. Also, an irrigation pond and three streams in the Conestoga River watershed near the Chesapeake Bay had both estrogen and testosterone. Each of these sites were affected by fields receiving poultry litter (Shore et al., 1995). Runoff from fields with land-applied manure has been reported to contain estrogens, estradiol, progesterone, and testosterone, as well as their synthetic counterparts. Estrogens have also been found in runoff from heavily grazed land (Addis et al., 1999).

Other Pollutants

There has been almost no research on losses of pesticides in runoff from manured lands. A 1999 literature review by the University of Minnesota discussed a 1994 study showing that losses of cyromazine (used to control flies in poultry litter) in runoff increased with the rate of poultry manure application and the intensity of rainfall. The 1999 literature review also includes a 1995 study documenting that about 1 percent of all pesticides enter surface water. However, the magnitude of the impacts of these losses on surface water are unknown (Mulla, 1999). In general, little information is available regarding the fate and transport of pesticides or their bioavailability in waste-amended soils. Furthermore, there is little information comparing potential releases of these compounds from animal waste to other sources such as municipal and industrial wastewaters, septic tank leachate, runoff from land-applied sewage sludge, crop runoff, and urban runoff.

3. POTENTIAL HAZARDS FROM AFO POLLUTANTS

As described in Chapter 2, animal feeding operations are associated with a variety of pollutants, including nutrients (specifically nitrogen and phosphorus), ammonia, pathogens, organic matter, salts, trace elements, solids, antibiotics, hormones, gas and particulate emissions, and pesticides. These AFO pollutants can produce multimedia impacts, such as the following:

- Surface water. Impacts have been associated with surface discharges of waste, as well as leaching to ground water and subsurface flow to surface water. Generally, states with high concentrations of feedlots experience 20 to 30 serious water quality pollution problems per year involving manure lagoon spills and feedlot runoff (Mulla, 1999). The waste's oxygen demand and ammonia content can result in fish kills and reduced biodiversity. Solids can increase turbidity and impact benthic organisms. Nutrients contribute to eutrophication and associated algae blooms. Algal decay and nighttime respiration can depress dissolved oxygen levels, potentially leading to fish kills and reduced biodiversity. Eutrophication is also a factor in blooms of toxic algae and other toxic microorganisms, such as Pfiesteria piscicida. Human and animal health impacts are primarily associated with drinking contaminated water (pathogens and nitrates), coming into contact with contaminated water (pathogens such as toxic algae and *Pfiesteria*), and consuming contaminated shellfish (pathogens such as toxic algae). Trace elements (e.g., arsenic, copper, selenium, and zinc) may also present human health and ecological risks. Salts contribute to salinization and disruption of ecosystem balance, as well as degradation of drinking water supplies. Antibiotics, pesticides, and hormones may have low-level, long-term ecosystem effects.
- Ground water. Impacts have been associated with pollutants leaching to ground
 water. Human and animal health impacts are associated with pathogens and nitrates
 in drinking water. Leaching salts can increase health risks to salt-sensitive
 individuals, and can make the water unpalatable. Trace elements, antibiotics,
 pesticides, and hormones may also present human health and ecological risks through
 ground water pathways.
- Air. Air impacts include human health effects from ammonia, hydrogen sulfide, other odor-causing compounds, particulates, and the contribution to global climate change due to methane emissions. In addition, volatilized ammonia can be redeposited on the earth and contribute to eutrophication.
- Soil. Trace elements and salts in animal manure can accumulate in soil and become toxic to plants. Salts also deteriorate soil quality by leading to reduced permeability and overall poor physical condition. Crops may provide a human and animal exposure pathway for trace elements and pathogens.

This chapter describes in greater detail the known or potential adverse human health and ecological effects of AFO pollutants.

3.1 PRIMARY NUTRIENTS

This section reviews the hazards posed by primary nutrients in animal manure. It focuses on nitrogen and phosphorus, which have received the greatest attention in the scientific literature. Actual or anticipated levels of potassium in ground water and surface water are unlikely to pose hazards to aquatic life or human health (Wetzel, 1983). Potassium does contribute to salinity, however, and applications of high salinity manure are likely to decrease the fertility of the soil.

3.1.1 Ecology

Eutrophication

Eutrophication is the process in which phosphorus and nitrogen over-enrich a waterbody and disrupt the balance of life in that waterbody. Perhaps the most documented impact of nutrient pollution is the increase in surface water eutrophication (nutrient enrichment) and its effects on aquatic ecosystems (Vallentyne, 1974). Although nutrients are essential for the growth of phytoplankton (free-floating algae), periphyton (attached algae), and aquatic plants, which form the base of the aquatic food web, the overabundance of nutrients can lead to harmful algal blooms and other adverse effects, such as:

- · Increased biomass of phytoplankton;
- Shifts in phytoplankton to bloom-forming species that may be toxic or inedible;
- · Changes in macrophyte species composition and biomass;
- Death of coral reefs and loss of coral reef communities;
- Decreases in water transparency;
- Taste, odor, and water treatment problems;
- Oxygen depletion;
- Increased incidence of fish kills;
- Loss of desirable fish species;
- · Reductions in harvestable fish and shellfish; and
- Decreases in aesthetic value of the waterbody (Carpenter et al., 1998).

The type of waterbody impacted may dictate which nutrient (nitrogen or phosphorus) will have the most impact. In estuaries and coastal marine waters, nitrogen is typically the limiting nutrient (i.e., in these waters, phosphorus levels are sufficiently high compared to nitrogen such that small changes in nitrogen concentrations have a greater effect on plant growth). In fresh waters, phosphorus is typically the limiting nutrient (Wendt and Corey, 1980; Robinson and Sharpley, 1995). There can be exceptions to this generalization, however, especially in waterbodies with heavy pollutant loads. For example, estuarine systems may become phosphorus-limited when nitrogen concentrations are high. In such cases, excess phosphorus will produce algal blooms (North Carolina's Nicholas School of the Environment's Agricultural Animal Waste Task Force, 1994). Thus, both nitrogen and phosphorus loads can contribute to eutrophication in either water type.

Algae and Other Toxic Microorganisms

Eutrophication causes the enhanced growth and subsequent decay of algae, which can lower dissolved oxygen content of a waterbody to levels insufficient to support fish and invertebrates. In some cases, this situation can produce large areas devoid of life because of a lack of sufficient dissolved oxygen. One extreme example is the "Dead Zone," an area of hypoxic water larger than 10,000 km² that spreads off the Louisiana coast in the Gulf of Mexico each summer. The Dead Zone is believed to be caused by excess chemical fertilizer; however, nutrients from animal waste have also contributed to the problem. This condition has been attributed to excess nutrients delivered primarily by the Mississippi and Atchafalaya river systems (Atwood et al., 1994). The problem in the Gulf demonstrates that pollutant discharges can have far-reaching downstream impacts. In fact, the nutrient loadings to the Gulf originate from sources over a large land area covering approximately 41 percent of the conterminous United States (Goolsby et al., 1999).

Eutrophication can also affect phytoplankton and zooplankton population diversity, abundance, and biomass, and increase the mortality rates of aquatic species. For example, floating algal mats can prevent sunlight from reaching submerged aquatic vegetation, which serves as habitat for fish spawning, juvenile fish, and fish prey (e.g., aquatic insects). The resulting decrease in submerged aquatic vegetation adversely affects both fish and shellfish populations (USEPA, 2000a).

Another effect of eutrophication is increased incidence of harmful algal blooms, which release toxins as they die and can severely impact wildlife as well as humans. In marine ecosystems, blooms known as red or brown tides have caused significant mortality in marine mammals (Carpenter et al., 1998). In fresh water, cyanobacterial toxins have caused many incidents of poisoning of wild and domestic animals that have consumed impacted waters (Health Canada Environmental Health Program, 1998). Published reports of wildlife poisoning from these blooms include amphibians, fish, snakes, waterfowl, raptors, and deer (USFWS, 2000).

Eutrophication is also associated with blooms of other toxic organisms, such as the estuarine dinoflagellate *Pfiesteria piscicida*. *Pfiesteria* has been implicated as the primary causative agent of many major fish kills and fish disease events in North Carolina estuaries and coastal areas (NCSU, 2000), as well as in Maryland and Virginia tributaries to the Chesapeake Bay (USEPA, 1997b). *Pfiesteria* often lives as a nontoxic predatory animal, becoming toxic in response to human influences including excessive nutrient enrichment (NCSU, 2000). While nutrient-enriched conditions are not required for toxic outbreaks to occur, excessive nutrient loadings are a concern because they help create an environment rich in microbial prey and organic matter that *Pfiesteria* uses as a food supply. By increasing the concentration of *Pfiesteria*, nutrient loads increase the likelihood of a toxic outbreak when adequate numbers of fish are present (Citizens *Pfiesteria* Action Commission, 1997). Researchers have documented stimulation of *Pfiesteria* growth by human sewage and swine effluent spills and have shown that the organism's growth can be highly stimulated by both inorganic and organic nitrogen and phosphorus enrichments (NCSU, 2000).

Increased algal growth can also raise the pH of waterbodies, as algae consume dissolved carbon dioxide to support photosynthesis. Many biological processes, including reproduction, cannot function in water that is very acidic or alkaline (USEPA, 2000a).

Nitrites

Nitrites can also pose a risk to aquatic life: if sediments are enriched with nutrients, the concentrations of nitrites in the overlying water may be raised enough to cause nitrite poisoning or "brown blood disease" in fish (USDA, 1992). In addition, excess nitrogen can contribute to water quality decline by increasing the acidity of surface waters.

3.1.2 Human Health

Nitrates/Nitrites

The main hazard to human health from primary nutrients is elevated nitrate levels in drinking water. In particular, infants are at risk from nitrate poisoning (also referred to as methemoglobinemia or "blue baby syndrome"), which can be fatal. This poisoning results in oxygen starvation and is due to nitrite (a metabolite of nitrate), which is formed in the environment, foods, and the human digestive system. Compared to adults and older children, infants under six months experience elevated nitrite production because their digestive systems have a higher concentration of nitrate-reducing bacteria. Nitrite oxidizes iron in the hemoglobin of red blood cells to form methemoglobin, which cannot carry sufficient oxygen to the body's cells and tissues. Although methemoglobin is continually produced in humans, an enzyme in the human body reduces methemoglobin back to hemoglobin. In most individuals, this conversion occurs rapidly. Infants, however, have a low concentration of methemoglobin-reducing enzyme, as do individuals with an enzyme deficiency. In these people, methemoglobin is not converted to hemoglobin as readily (Nebraska Cooperative Extension, 1995).

Because infants under six months have a higher concentration of digestive bacteria that reduce nitrates, and a lower concentration of methemoglobin-reducing enzyme, they are at higher risk for methemoglobinemia (Nebraska Cooperative Extension, 1995). To protect infant health, the EPA set drinking water Maximum Contaminant Levels (MCLs) of 10 mg/L for nitrate-nitrogen and 1 mg/L for nitrite-nitrogen. MCLs are the maximum permissible levels of pollutants allowed in water delivered to public drinking water systems. Once a water source is contaminated, the costs of protecting consumers from nitrate exposure can be significant. Nitrate is not removed by conventional drinking water treatment processes. Its removal requires additional, relatively expensive treatment units.

Although reported cases of methemoglobinemia are rare, the incidence of actual cases may be greater than the number reported. Studies in South Dakota and Nebraska have indicated that most cases of methemoglobinemia are not reported (Michel et al., 1996; Meyer, 1994). For example, in South Dakota between 1950 and 1980, only two cases were reported, while at least

¹⁰ Brown blood disease is named for the color of the blood of dead or dying fish, indicating that the hemoglobin has been converted to methemoglobin.

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80 were estimated to have occurred (Meyer, 1994). There are at least two reasons for this underreporting. First, methemoglobinemia can be difficult to detect in infants because its symptoms are similar to other conditions (Michel et al., 1996). In addition, doctors are not always required to report it (Michel et al., 1996).

In addition to blue baby syndrome, low blood oxygen due to methemoglobinemia has also been linked to birth defects, miscarriages, and general poor health in humans and animals. These effects are exacerbated by concurrent exposure to many species of bacteria in water (IRIS, 2000). Studies in Australia found an increased risk of congenital malformations with consumption of high-nitrate ground water (Bruning-Fann and Kaneene, 1993). Multi-generation animal studies have found decreases in birth weight, post-natal growth, and organ weights among mammals prenatally exposed to nitrite (IRIS, 2000). Nitrate- and nitrite-containing compounds may also cause hypotension or circulatory collapse (Bruning-Fann and Kaneene, 1993).

High nitrate levels in drinking water have also been implicated in higher rates of stomach and esophageal cancer, although a 1995 National Research Council report concludes that exposure to nitrate and nitrite concentrations in drinking water are unlikely to contribute to human cancer risks (National Research Council, 1995). However, nitrate metabolites such as N-nitroso compounds (especially nitrosamines) have been linked to severe human health effects such as gastric cancer (Bruning-Fann and Kaneene, 1993). The formation of N-nitroso compounds occurs in the presence of catalytic bacteria (e.g., those found in the stomach) or thiocyanate.

Generally, people drawing water from domestic wells are at greater risk of nitrate poisoning than those drawing from public wells (Nolan and Ruddy, 1996), since domestic wells are typically shallower and not subject to wellhead protection or monitoring requirements. Reported cases of methemoglobinemia are most often associated with wells that were privately dug and that may have been badly positioned in relation to the disposal of human and animal excreta (Addiscott et al., 1991). Furthermore, people served by public systems are better protected even if the water becomes contaminated, due to water quality monitoring and treatment requirements.

Phosphorus

Animal manure also contributes to increased phosphorus concentrations in water supplies. Previous evaluations of phosphorus have not identified significant adverse human health effects, but phosphate levels greater than 1.0 mg/L may interfere with coagulation in drinking water treatment plants and thereby increase treatment costs (North Carolina's Nicholas School of the Environment's Agricultural Animal Waste Task Force, 1994).

Eutrophication/Algal Blooms

To the extent that nitrogen and phosphorus contribute to algal blooms in surface water through accelerated eutrophication as described in Section 3.1.1, these nutrients can reduce the aesthetic and recreational value of surface water resources. Algae can affect drinking water by clogging treatment plant intakes, producing objectionable tastes and odors. Algae can also increase production of harmful chlorinated byproducts (e.g., trihalomethanes) by reacting with chlorine

used to disinfect drinking water. These impacts result in increased costs of drinking water treatment, reduced drinking water quality, and/or increased health risks.

Eutrophication can also affect human health by enhancing growth of harmful algal blooms that release toxins as they die. In marine ecosystems, harmful algal blooms such as red tides can result in human health impacts via shellfish poisoning and recreational contact (Thomann and Mueller, 1987). In fresh water, blooms of cyanobacteria (blue-green algae) may pose a serious health hazard to humans via water consumption. When cyanobacterial blooms die or are ingested, they release water-soluble compounds that are toxic to the nervous system and liver (Carpenter et al., 1998).

In addition, eutrophication is associated with blooms of a variety of other organisms that are toxic to humans, such as the estuarine dinoflagellate *Pfiesteria piscicida*. While *Pfiesteria* is primarily associated with fish kills and fish disease events, the organism has also been linked with human health impacts through dermal or inhalation exposure. Researchers working with dilute toxic cultures of *Pfiesteria* exhibited symptoms such as skin sores, severe headaches, blurred vision, nausea/vomiting, sustained difficulty breathing, kidney and liver dysfunction, acute short-term memory loss, and severe cognitive impairment (NCSU, 2000). People with heavy environmental exposure have exhibited symptoms as well. In a 1998 study, such environmental exposure was definitively linked with cognitive impairment and less consistently linked with physical symptoms (Morris et al., 1998).

3.2 AMMONIA

3.2.1 Ecology

Ammonia exerts a direct biochemical oxygen demand (BOD) on the receiving water. As ammonia is oxidized, dissolved oxygen is consumed. Moderate depressions of dissolved oxygen are associated with reduced species diversity, while more severe depressions can produce fish kills. In fact, ammonia is a leading cause of fish kills (USDA, 1992). Ammonia-induced fish kills are a potential consequence of the discharge of animal wastes directly to surface waters. For example, in a May 1997 incident in Wabasha County, Minnesota, ammonia in a dairy cattle manure discharge killed 16,500 minnows and white suckers (Clean Water Action Alliance, 1998). Additionally, ammonia loadings can contribute to accelerated eutrophication of surface waters, which can significantly impact aquatic ecosystems in a number of ways, as noted above.

3.2.2 Human Health

Ammonia is a nutrient form of nitrogen that can have several impacts. First, volatilized ammonia is of concern because of direct localized impacts on air quality. Ammonia produces an objectionable odor and can cause nasal and respiratory irritation.

In addition, ammonia contributes to eutrophication of surface waters. This phenomenon is primarily a hazard to aquatic life but is also associated with human health impacts (see Section 3.1.2). As previously mentioned, eutrophication reduces the aesthetic and recreational value of water bodies. Additionally, the associated algae blooms can affect drinking water by clogging

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treatment plant intakes, producing objectionable tastes and odors, and increasing production of harmful chlorinated byproducts. These impacts result in increased drinking water treatment costs, reduced drinking water quality, and/or increased health risks. Eutrophication can also impact human health by enhancing the growth of toxic algae and other toxic organisms.

3.3 PATHOGENS

3.3.1 Ecology

Animal wastes carry parasites, bacteria, and viruses, many of which have the potential to be harmful to wildlife (USDA, 1992; Jackson et al., 1987). Some bacteria in livestock waste cause avian botulism and avian cholera, which have killed thousands of migratory waterfowl in the past (USEPA, 1993b). Avian botulism is a food poisoning caused by ingestion of a neurotoxin produced by the bacterium *Clostridium botulinum* type C., and *Salmonella* spp, both of which naturally occur in the intestinal tract of warm-blooded animals (USFWS, 2000).

Pathogens in surface water can adhere to the skin of fish or be taken up internally when present at high enough concentrations. In a controlled experiment, Fattal et al. (1992) detected significant bacterial concentrations in fish exposed to *Escherichia coli* and other microorganisms for up to 48 hours. The data suggest that harmful pathogens could be taken up by fish-eating carnivores feeding in contaminated surface waters.

Shellfish are filter feeders that pass large volumes of water over their gills. As a result, they can concentrate a broad range of microorganisms in their tissues (Chai et al., 1994). This provides a pathway for pathogen transmission to higher trophic organisms. However, little information is available to assess the health effects of contaminated shellfish on wildlife receptors.

3.3.2 Human Health

Pathogens may be transmitted to humans through contaminated surface water or ground water used for drinking, or by direct contact with contaminated surface water through recreational uses. By the year 2010, about 20 percent of the human population (especially infants, the elderly, and those with compromised immune systems) will be classified as particularly vulnerable to the health effects of pathogens (Mulla, 1999). Over 150 pathogens in livestock manure are associated with risks to humans (CAST, 1992). Exhibit 3-1 presents a list of several of these pathogens and their associated diseases, including salmonellosis, cryptosporidiosis, and giardiasis. Other pathogens that have been associated with livestock waste include those that cause cholera, typhoid fever, and polio (USEPA, 1993b). Many of these pathogens are transmitted to humans via the fecal-oral route. In the water environment, humans may be exposed to pathogens through consumption of contaminated drinking water (although the EPA assumes adequate drinking water treatment of public supplies), or by incidental ingestion during recreational activities in contaminated waters.

EXHIBIT 3-1 Some Diseases and Parasites Transmittable to Humans from Animal Manure ^a

Disease	Responsible Organism	Symptoms		
Bacteria				
Anthrax	Bacillus anthracis	Skin sores, fever, chills, lethargy, headache, nausea, vomiting, shortness of breath, cough, nose/throat congestion, pneumonia, joint stiffness, joint pain		
Brucellosis	Brucella abortus, Brucella melitensis, Brucella suis	Weakness, lethargy, fever, chills, sweating, headache		
Colibaciliosis	Escherichia coli (some serotypes)	Diarrhea, abdominal gas		
Coliform mastitis- metritis	Escherichia coli (some serotypes)	Diarrhea, abdominal gas		
Erysipelas	Erysipelothrix rhusiopathiae	Skin inflammation, rash, facial swelling, fever, chills, sweating, joint stiffness, muscle aches, headache, nausea, vomiting		
Leptospirosis	Leptospira pomona	Abdominal pain, muscle pain, vomiting, fever		
Listeriosis	Listeria monocytogenes	Fever, fatigue, nausea, vomiting, diarrhea		
Salmonellosis	Salmonella species	Abdominal pain, diarrhea, nausea, chills, fever, headache		
Tetanus	Clostridium tetani	Violent muscle spasms, "lockjaw" spasms of jaw muscles, difficulty breathing		
Tuberculosis	Mycobacterium tuberculosis, Mycobacterium avium	Cough, fatigue, fever, pain in chest, back, and/or kidneys		
Rickettsia				
Q fever	Coxiella burneti	Fever, headache, muscle pains, joint pain, dry cough, chest pain, abdominal pain, jaundice		
Viruses				
Foot and Mouth	virus	Rash, sore throat, fever		
Swine Cholera	virus			
New Castle	virus			
Psittacosis	virus	Pneumonia		
Fungi				
Coccidioidomycosis	Coccidioides immitus	Cough, chest pain, fever, chills, sweating, headache, muscle stiffness, joint stiffness, rash wheezing		
Histoplasmosis	Histoplasma capsulatum	Fever, chills, muscle ache, muscle stiffness, cough, rash, joint pain, joint stiffness		
Ringworm	Various microsporum and trichophyton	Itching, rash		
Protozoa				
Balantidiasis	Balatidium coli			

Disease	Responsible Organism	Symptoms			
Coccidiosis	Eimeria species	Diarrhea, abdominal gas			
Cryptosporidiosis	Cryptosporidium parvum	Watery diarrhea, dehydration, weakness, abdominal cramping			
Giardiasis	Giardia lamblia	Diarrhea, abdominal pain, abdominal gas, nausea, vomiting, headache, fever			
Toxoplasmosis	Toxoplasma species	Headache, lethargy, seizures, reduced cognitive function			
Parasites/Metazoa					
Ascariasis	Ascaris lumbricoides	Worms in stool or vomit, fever, cough, abdominal pain, bloody sputum, wheezing, skin rash, shortness of breath			
Sarcocystiasis	Sarcosystis species	Fever, diarrhea, abdominal pain			

Sources: Diseases and organisms were compiled from USDA/NRCS (1996) and USEPA (1998). Symptom descriptions were obtained from various medical and public health service Internet sites.

Although a wide range of organisms may cause disease in humans, relatively few microbial agents are responsible for the majority of human disease outbreaks from water-based exposure routes. This point is illustrated by Exhibit 3-2, which presents reports of waterborne disease outbreaks and their causes (if known) in the United States for the period 1989-1996. Intestinal infections are the most common type of waterborne infection, and affect the most people.

As presented in Exhibit 3-2, most reported outbreaks were associated with protozoa and bacteria. As noted in Exhibit 3-1, *Cryptosporidium parvum* can produce gastrointestinal illness, with symptoms such as severe diarrhea. Relatively low doses of both *Cryptosporidium parvum* as well as *Giardia* species are needed to cause infection (Stehman, 2000). Although healthy people typically recover relatively quickly (within 2 to 10 days) from this type of illness, these diseases can be fatal in people with weakened immune systems. These individuals typically include children, the elderly, people with human immunovirus (HIV) infection, chemotherapy patients, and those taking medications that suppress the immune system.

^a Pathogens in animal manure are a potential source of disease in humans and other animals. This list represents a sampling of diseases that may be transmittable to humans.

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EXHIBIT 3-2
Etiology of Waterborne Disease Outbreaks Causing Gastroenteritis 1989-1996

Type of	Etiologic Agent	Total Number of Outbreaks	Outbreaks Associated with Drinking Water		Outbreaks Associated with Recreational Water	
Organism			Surface	Ground	Natural	Pool/ Park
D.	Giardia spp.	27	12	6	4	5
Protozoa	Cryptosporidium parvum	21	4	4	2	11
	Escherichia coli O157:H7	11	-	3	7	1
Bacteria with Potential for	Campylobacter jejuni	3	3	-	-	-
Infecting	Salmonella typhimurium	1	-	1	-	-
Multiple Species	Salmonella java	1	-	-	-	1
	Leptospira grippotyphosa	1	-	-	1	-
Bacterial Infections	Shigella sonnei	17	-	7	10	-
Associated with Humans	Shigella flexneri	2	-	1	1	-
	Hepatitis A	3	-	-	-	3
11	Norwalk virus	1	-	1	-	-
Human viruses	Norwalk-like virus	1	-	-	-	1
	Small round structured virus	1	1	-	-	-
Acute Gastroenteritis	Unidentified etiology- many consistent with viral epidemiology	60	8	44	7	1
Other	Cyanobacteria-like bodies	1	11	-	-	-

Source: Stehman, 2000.

Exhibit 3-2 shows that infections caused by *Giardia* species and *Cryptosporidium parvum* (considered the two most important waterborne protozoa) were the leading causes of infectious waterborne disease outbreaks in which an agent was identified, both for total cases and for number of outbreaks (Mulla, 1999; Stehman, 2000). In 1993 in Milwaukee, Wisconsin, *Cryptosporidium parvum* contamination of a public water supply caused more than 100 deaths and an estimated 403,000 illnesses (Smith, 1994; Casman, 1996). The outbreak cost an estimated \$37 million in lost wages and productivity (Smith, 1994). The source of the oocysts was not identified, but speculated sources include runoff from cow manure application sites, wastewater from a slaughterhouse and meat packing plant, and municipal wastewater treatment

plant effluent (Casman, 1996). Four documented cases of cryptosporidiosis occurring since 1984 have been linked to non-point source agricultural pollution (Mulla, 1999). Two outbreaks of *Cryptosporidium parvum* were also traced to contamination of drinking water by cow manure in England (Stehman, 2000).

The mandated treatment of public water supplies helps reduce the risk of infection via drinking water, but the first step in providing safe drinking water is source water protection, especially because *Cryptosporidium parvum* is resistant to conventional treatment.

Escherichia coli is an important cause of bacterial waterborne infection in untreated and recreational water (Stehman, 2000). Infection can be life-threatening, especially in the young and in the elderly. It can cause bloody diarrhea and, if not treated promptly, can result in kidney failure and death (Shelton, 2000). In particular, Escherichia coli O157:H7 is emerging as the second most important cause of bacterial waterborne disease after Shigella species, which is associated with human feces. Escherichia coli O157:H7 was unknown until 1982, when it was associated with a multistate outbreak of hemorrhagic colitis (Shelton, 2000). In 1999, an Escherichia coli outbreak occurred at the Washington County Fair in New York State. This outbreak was possibly the largest waterborne outbreak of Escherichia coli O157:H7 in U.S. history. It took the lives of two fair attendees and sent 71 others to the hospital. An investigation identified 781 persons with confirmed or suspected illness related to this outbreak. The outbreak is thought to have been caused by contamination of the Fair's Well 6 by either a dormitory septic system or manure runoff from the nearby Youth Cattle Barn (NYSDOH, 2000). More recently, in May 2000, an outbreak of Escherichia coli O157:H7 in Walkerton, Ontario resulted in at least seven deaths and 1,000 cases of intestinal problems; public health officials theorize that one possible cause was floodwaters washing manure contaminated with Escherichia coli into the town's drinking water well; an investigation is currently underway (Brooke, 2000). An outbreak of Escherichia coli O157:H7 was reported in Canada from well water potentially contaminated by manure runoff (Stehman, 2000).

Cow manure has specifically been implicated as a causative factor in the high bacteria levels and ensuing swimming restrictions on Tainter Lake, Wisconsin (Behm, 1989). Contact recreation can result in infections of the skin, eye, ear, nose, and throat (Juranek, 1995; Stehman, 2000). The EPA's recommended ambient water quality standard for human health protection in contact-recreational fresh waters is either 120 *Escherichia coli* bacteria/100 ml, or 33 enterococcus bacteria/100 ml. (This standard, finalized in 1986, replaces the previous standard of 200 fecal coliform bacteria/100 ml.) About 8 percent of U.S. outbreaks of *Escherichia coli* O157:H7 between the years 1982 and 1996 occurred as a result of swimming (Griffin, 1998). Certain regions, in particular, may be adversely impacted. For example, pathogen impairment of surface waters is a great problem in most rural areas of southern Minnesota. This causes many rivers and lakes to be unsuitable for swimming (Mulla, 1999).

Most human infections caused by bacteria such as *Escherichia coli* O157:H7, *Salmonella* species, Campylobacter jejuni, and *Leptospira* species are spread by foodborne or direct contact (Stehman, 2000). Many pathogens might be transmitted through shellfish (Stehma and McCabe,

1992), which are filter feeders prone to accumulating bacteria and viruses. Others may be transmitted through inhalation. In particular, there is concern that pathogens may also be introduced to the air directly from animal feeding houses or during spray application of wastes. Flies and other vectors also present potential pathways for disease transmission.

A final concern is exposure to pathogens via consumption of raw foods improperly subjected to manure application. Cieslak et al. (1993) suggest that a 1993 *Escherichia coli* outbreak in Maine was the result of manure applications to a vegetable garden. Additionally, three *Escherichia coli* outbreaks (Montana in 1995, Illinois in 1996, and Connecticut in 1996) were traced to organic lettuce growers. It is suspected that the lettuces were contaminated by infected cattle manure (Nelson, 1997). In another incident in Maine, a few hundred children were sickened by *Cryptosporidium parvum*. The source was fresh-pressed apple cider made from apples gathered from a cattle pasture (Millard et al., 1994). Although this exposure route can cause health problems, the proposed revisions to the EPA regulations do not attempt to address it directly.

3.4 ORGANIC MATTER

3.4.1 Ecology

Increased organic matter loading to surface waters supports increased microbial population and activity; as these organisms aerobically degrade the organic matter, dissolved oxygen is consumed, reducing the amount available for aquatic organisms. This impact is exacerbated in warm waters compared to colder waters, because the dissolved oxygen saturation level is lower and because the higher temperatures support increased microbial metabolism.

As a result of dissolved oxygen depletion, aquatic species may suffocate (USEPA, 1993a) or be driven out of areas that lack sufficient oxygen. This phenomenon can occur rapidly, particularly with loadings of high-strength waste such as those that may result from catastrophic lagoon breaches (Goldman and Horne, 1983). There are many examples nationwide of fish kills resulting from manure discharges from animal feeding operations (see Chapter 4). In Nebraska in 1995, 50 percent of all agriculture-related fish kills investigated were due to livestock waste. In 1996, that percentage rose to 75 percent. In 1997 and 1998, 100 percent of agriculture-related fish kills were traced to livestock waste (USFWS, 2000).

Oxygen-stressed aquatic systems may also experience decreases in species richness or community structure as sensitive species are driven out or die off. Organisms living in borderline hypoxic (low oxygen) water are also likely to experience physiological stress, which may increase the potential for diseases, decrease feeding rates, or increase predation. Livestock has been widely reported to cause significant decreases in wildlife species and numbers (Mulla et al., 1999). For example, reduction in biodiversity due to AFOs has been documented in a study of three Indiana stream systems (Hoosier Environmental Council, 1997). That study shows that waters downstream of animal feedlots (mainly swine and dairy operations) contained fewer fish and a limited number of species of fish in comparison with reference sites. Excessive algal

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growth; altered oxygen content; and increased levels of ammonia, turbidity, pH, and total dissolved solids were also observed.

High oxygen depletion rates due to microbial activity have been reported in manure-amended agricultural soils as well. In soils, elevated microbial populations can affect crop growth by competing with plant roots for soil oxygen and nutrients (USDA, 1992).

3.4.2 Human Health

The release of organic matter to surface waters is a human health concern insofar as it can impact drinking water sources and recreational waters. As aquatic bacteria and other microorganisms degrade organic matter in manure, they consume dissolved oxygen. This can lead to foul odors and ecological impacts, reducing the water's value as a source of drinking water and recreation. Additionally, increased organic matter in drinking water sources can lead to excessive production of harmful chlorinated byproducts, resulting in higher drinking water treatment costs and/or higher health risks. Pathogen growth is another concern, as large inflows of nutrient-rich organic matter, under the right environmental conditions, can cause rapid increases in microbial populations.

3.5 SALTS AND TRACE ELEMENTS

3.5.1 Ecology

Salts in manure can impact the water and soil environment. In fresh waters, increasing salinity can disrupt the balance of the ecosystem. Drinking water high in salt content was shown to inhibit growth and cause slowed molting in mallard ducklings (IEC, 1993). On land, salts can accumulate and become toxic to plants, and reduce crop yields. Salts can damage soil quality by reducing permeability and deteriorating soil structure (Bloom, 1999).

Trace elements in manure can impact plants, aquatic organisms, and terrestrial organisms. While many of the trace elements are essential nutrients at low concentrations, they can have significant ecotoxicological effects at elevated concentrations. For example, metals such as zinc (a feed additive) can accumulate in soil and become toxic to plants at high concentrations. Arsenic, copper, and selenium are other feed additives that can produce aquatic and terrestrial toxicity at elevated concentrations. Bottom feeding birds can be quite susceptible to metal toxicity because they are attracted to shallow feedlot wastewater ponds and waters adjacent to feedlots. Metals can remain in aquatic ecosystems for long periods of time because of adsorption to suspended or bed sediments or uptake by aquatic biota.

Several of the trace elements in manure are regulated in treated municipal sewage sludge (but not manure) by the Clean Water Act's Part 503 Rule. Total concentrations of trace elements in animal manures have been reported as comparable to those in some municipal sludges, with typical values well below the maximum concentrations allowed by Part 503 for land-applied sewage sludge (Sims, 1995). Based on this information, trace elements in agronomically applied

manures should pose little risk to human health and the environment. However, repeated application of manures above agronomic rates could result in exceedances of the cumulative metal loading rates established in Part 503, thereby potentially impacting human health and the environment (USFWS, 1991).

In 1991, the U.S. Fish and Wildlife Service (USFWS) reported on suspected impacts from a large number of cattle feedlots on Tierra Blanca Creek, upstream of the Buffalo Lake National Wildlife Refuge in the Texas Panhandle. USFWS found elevated concentrations of the feed additives copper and zinc in the creek sediment (as well as elevated aqueous concentrations of ammonia, chemical oxygen demand, chlorophyll *a*, coliform bacteria, chloride, conductivity, total Kjeldahl nitrogen, and volatile suspended solids). The relative contribution of these contaminants from various sources (e.g., runoff from facilities without containment lagoons, lagoon discharges, and lagoon leachate) was not assessed (USFWS, 1991).

In 1998, USFWS found copper and zinc in wetlands fed by wastewater from a nearby swine production operation in Nebraska. Concentrations of copper exceeded both a proposed aquatic life criterion of 43 μ g/L and the current least-protective criterion of 121 μ g/L. Zinc concentrations exceeded the concentrations recommended for the protection of aquatic life (USFWS, 2000).

3.5.2 Human Health

Salts from manure can impact surface and ground water drinking water sources. Salt load into the Chino Basin from local dairies is over 1,500 tons per year, and the cost to remove that salt by the drinking water treatment system ranges from \$320 to \$690 for every ton (USEPA, 1993b). At lower levels, salts can increase blood pressure in salt-sensitive individuals, increasing the risk of stroke and heart attack. Salts can also make drinking water unpalatable and unsuitable for human consumption.

Some of the trace elements in manure are essential nutrients required for human physiology; however, they can induce toxicity at elevated concentrations. These include zinc, arsenic, copper, and selenium, which are feed additives (Sims, 1995). Although these elements are typically present in relatively low concentrations in manure, they are of concern because of their ability to persist in the environment and to bioconcentrate in plant and animal tissues. These elements could pose a hazard if manure is overapplied to land, due to insufficient acreage available to accommodate manure from increasingly concentrated AFOs. Over-applied manure increases the likelihood of pollutants reaching surface water and ultimately being ingested.

Trace elements are associated with a variety of illnesses. For example, arsenic is carcinogenic to humans, based on evidence from human studies; some of these studies have found increased skin cancer and mortality from multiple internal organ cancers in populations who consumed drinking water with high levels of inorganic arsenic. Arsenic is also linked with non-cancer effects, including hyperpigmentation and possible vascular complications. Selenium is associated with

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liver dysfunction and loss of hair and nails, and zinc can result in changes in copper and iron balances, particularly copper deficiency anemia (IRIS, 2000).

3.6 SOLIDS

Excessive silting and sedimentation are prime agents responsible for the long-term degradation of rivers, streams, and lakes. Major sources of siltation include runoff from agricultural, urban, and forest lands and other non-point sources (USEPA, 1992b).

Solids entering surface water can degrade aquatic ecosystems to the point of non-viability. Suspended particles can reduce the depth to which sunlight can reach, decreasing photosynthetic activity (and the resulting oxygen production) by plants and phytoplankton. The increased turbidity also limits the growth of desirable aquatic plants that serve as critical habitat for fish, crabs, and other aquatic organisms. In addition, suspended particles can clog fish gills, degrade feeding areas, and reduce visibility for sight feeders (Abt Associates, 1993), and can disrupt migration by interfering with fish's ability to detect chemical communication signals in water (Goldman and Horne, 1983). Sediment can smother eggs, interrupt the reproductive process, and alter or destroy habitat for fish and benthic organisms.

Solids can also degrade drinking water sources, thereby increasing treatment costs. Furthermore, solids provide a medium for the accumulation, transport, and storage of other pollutants, including nutrients, pathogens, and trace elements. Sediment-bound pollutants often have a long history of interaction with the water column through cycles of deposition, resuspension, and redeposition.

3.7 ANTIBIOTICS AND ANTIBIOTIC RESISTANCE

Antibiotic-resistant strains of bacteria develop as a result of continual exposure to antibiotics. Use of antibiotics in raising animals, especially broad spectrum antibiotics, is increasing. As a result, more strains of antibiotic-resistant pathogens are emerging, along with strains that are increasingly resistant (Mulla, 1999). Antibiotic-resistant forms of *Salmonella*, *Campylobacter*, *Escherichia coli*, and *Listeria* are known or suspected to exist. An antibiotic-resistant strain of the bacterium *Clostridium perfringens* was detected in the ground water below plots of land treated with swine manure, while it was nearly absent beneath unmanured plots.

Antibiotic resistance poses a significant health threat. In April 2000 the New England Journal of Medicine published an article that discussed the case of a 12-year-old boy infected with a strain of *Salmonella* that was resistant to no fewer than 13 antimicrobial agents (Fey et al., 2000). The cause of the child's illness is believed to be exposure to the cattle on his family's Nebraska ranch.

The Centers for Disease Control and Prevention, the Food and Drug Administration, and the National Institutes of Health issued a draft action plan in June 2000 to address the increase in antibiotic resistant diseases (CDCP, 2000). The plan is intended to combat antimicrobial

resistance through surveys, prevention and control activities, research, and product development. One of the action items involves conducting pilot studies to assess the impact of environmental contamination by antimicrobial drug residues and drug-resistant organisms that enter the soil or water from human and animal waste.

3.8 HORMONES AND ENDOCRINE DISRUPTION

The presence of estrogen and estrogen-like compounds in surface water has caused much concern. Their ultimate fate in the environment is unknown, although early studies indicate that no common soil or fecal bacteria can metabolize estrogen (Shore et al., 1995). When present in high concentrations, hormones in the environment are linked to reduced fertility, mutations, and the death of fish, and there is evidence that fish in some streams are experiencing endocrine disruption (Shore et al., 1995; Mulla, 1999).

Estradiol, an estrogen hormone, was found in runoff from a field receiving poultry litter at concentrations up to $3.5 \,\mu\text{g/L}$. Fish exposed to $0.25 \,\mu\text{g/L}$ of estradiol often have gender changes; exposures at levels above $10 \,\mu\text{g/L}$ can be fatal (Mulla, 1999). Estrogen levels of $10 \,\mu\text{g/L}$ have been shown to affect trout (Shore et al., 1995).

Endocrine disruptors have also been the subject of increasing concern because they alter hormone pathways that regulate reproductive processes in both human and animal populations. Estrogen hormones have been implicated in the drastic reduction in sperm counts among European and North American men (Sharpe and Skakkebaek, 1993) and widespread reproductive disorders in a variety of wildlife (Colburn et al., 1993). A number of agricultural chemicals have also been demonstrated to cause endocrine disruption as well, including pesticides (Shore et al., 1995). The effects of these chemicals on the environment and their impacts on human health through environmental exposures are not completely understood. They are currently being studied for neurobiological, developmental, reproductive, and carcinogenic effects (Tetra Tech, 2000a). The EPA is not aware of any studies done on the human health impact of hormones from watersheds that have impairment from animal manure.

3.9 OTHER POLLUTANTS OF CONCERN

3.9.1 Gas Emissions

Odor sources include animal confinement buildings, waste lagoons, and land application sites. As animal waste decomposes, various gases are produced. The primary gases associated with aerobic decomposition include carbon dioxide and ammonia. Gases associated with anaerobic conditions, which dominate in typical, unaerated animal waste lagoons, include methane, carbon dioxide, ammonia, hydrogen sulfide, and over 150 other odorous compounds (USDA, 1992; Bouzaher et al., 1993; O'Neill and Phillips, 1992). These include volatile fatty acids, phenols, mercaptans, aromatics, sulfides, and various esters, carbonyls, and amines. The decomposition process is desirable because it reduces the biochemical oxygen demand and pathogen content of the waste. However, many of the end products can produce negative impacts, including strong

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odors. Heavy odors are the most common complaint from neighbors of swine operations in particular (Agricultural Animal Waste Task Force, 1996).

Odor is itself a significant concern because of its documented effect on moods, such as increased tension, depression, and fatigue (Schiffman et al., 1995). Odor also has the potential for vector attraction and affects property values. Additionally, many of the odor-causing compounds can cause physical health impacts. For example, hydrogen sulfide is toxic, and ammonia gas is a nasal and respiratory irritant.

In 1996, the Minnesota Department of Health found levels of hydrogen sulfide gas at residences near AFOs that were high enough to cause symptoms such as headaches, nausea, vomiting, eye irritation, respiratory problems (including shallow breathing and coughing), achy joints, dizziness, fatigue, sore throats, swollen glands, tightness in the chest, irritability, insomnia, and blackouts (Addis et al., 1999). In an Iowa study, neighbors within two miles of a 4,000-sow swine facility reported more physical and mental health symptoms than a control group (Thu, 1998). These symptoms included chronic bronchitis, hyperactive airways, mucus membrane irritation, headache, nausea, tension, anger, fatigue, and confusion.

Methane and carbon dioxide are greenhouse gases that contribute to global warming. Methane also contributes to the formation of tropospheric ozone (a component of photochemical smog). Based on various EPA estimates (USEPA, 1989 and USEPA, 1992a), methane emissions from U.S. animal wastes are a very small contributor to the global warming effect.

3.9.2 Particulates

Sources of particulate emissions from AFOs may include dried manure, feed, skin, hair, and possibly bedding. The airborne particles make up an organic dust, which includes endotoxin (the toxic protoplasm liberated when a microorganism dies and disintegrates), adsorbed gases, and possibly steroids (Thu, 1995). At least 50 percent of dust emissions from swine production facilities are believed to be respirable. The main impact downwind appears to be respiratory irritation due to the inhalation of organic dusts. Studies indicate that the associated microbes generally are not infectious, but may induce inflammation (Thu, 1995).

3.9.3 Pesticides

Pesticides may pose risks to the environment, such as chronic aquatic toxicity, and human health effects, such as systemic toxicity. In a few studies, common herbicides have been shown to cause endocrine disruption. There is some evidence that fish in some streams are experiencing endocrine disruption and that contaminants including pesticides may be the cause (Mulla, 1999).

4. NATIONAL AND LOCAL IMPACTS OF ANIMAL AGRICULTURE

4.1 NATIONAL WATER QUALITY INVENTORY RESULTS

Agricultural operations, including AFOs, are a significant source of water pollution in the United States. The recently released *National Water Quality Inventory: 1998 Report to Congress* (USEPA, 2000a) was prepared under Section 305(b) of the Clean Water Act. Under this section of the Act, states and tribes report their impaired water bodies to the EPA, including the suspected sources of those impairments. The most recent report indicates that agriculture (which includes crop production, pasture and range grazing, concentrated and other confined animal feeding operations, and aquaculture) is the leading contributor to identified water quality impairments in the nation's rivers and lakes, and the fifth leading contributor to identified water quality impairments in the nation's estuaries (Exhibit 4-1).

EXHIBIT 4-1Five Leading Sources of Water Quality Impairment in the United States

Rank	Rivers	Lakes	Estuaries
1	Agriculture (59%)	Agriculture (31%)	Municipal Point Sources (28%)
2	Hydromodification (20%)	Hydromodification (15%)	Urban Runoff/Storm Sewers (28%)
3	Urban Runoff/Storm Sewers (11%)	Urban Runoff/Storm Sewers (12%)	Atmospheric Deposition (23%)
4	Municipal Point Sources (10%)	Municipal Point Sources (11%)	Industrial Discharges (15%)
5	Resource Extraction (9%)	Atmospheric Deposition (8%)	Agriculture (15%)

Source: USEPA (2000a).

Fraction of impairment attributed to each source is shown in parentheses. For example, agriculture is listed as a source of impairment in 59 percent of impaired river miles. The portion of "agricultural" impairment attributable to animal waste (as compared to crop production, pasture grazing, range grazing, and aquaculture) is not specified. Figure totals exceed 100 percent because water bodies may be impaired by more than one source.

Exhibit 4-2 presents additional summary statistics from the 1998 *National Water Quality Inventory*. These figures indicate that agriculture contributes to the impairment of at least 170,000 river miles, 2.4 million lake acres, and almost 2,000 estuarine square miles. The total portion of impairment attributable to animal agriculture nationwide is unknown, because only a portion of all states and tribes identified specific agricultural sources. Some conclusions, however, can be made based on the reporting states, as indicated in Exhibit 4-3.

¹¹This report can be found on the Internet at http://www.epa.gov/305b/98report.

EXHIBIT 4-2 Summary of U.S. Water Quality Impairment Survey

Total Quantity in U.S.	Waters Assessed	Quantity Impaired by All Sources	Quantity Impaired by Agriculture ^a
Rivers	23% of total	35% of assessed	59% of impaired
3,662,255 miles	840,402 miles	291,263 miles	170,750 miles
Lakes, Ponds, and Reservoirs	42% of total	45% of assessed	31% of impaired 2,417,801 acres
41.6 million acres	17.4 million acres	7.9 million acres	
Estuaries	32% of total	44% of assessed	15% of impaired
90,465 square miles	28,687 square miles	12,482 square miles	1,827 square miles

Source: USEPA (2000a).

EXHIBIT 4-3
Percent of Total Agricultural Impairment Contributed by Animal Agriculture

Type of Animal Agriculture	Rivers, Streams ^a	Lakes, Ponds, Reservoirs ^b
AFOs (Feedlots, Holding Areas, Other)	16	4
Range and Pasture Grazing	17	39

^a Based on reports from 28 states.

Note: Impairment due to land application of manure was not reported.

Exhibit 4-4 lists the leading pollutants impairing surface water quality in the United States. AFOs are a potential source of all listed pollutants, but are most commonly associated with nutrients, pathogens, oxygen-depleting substances, and solids (siltation). AFOs can also contribute to the growth of noxious aquatic plants due to the discharge of excess nutrients. Further, AFOs may contribute loadings of priority toxic organic chemicals and oil and grease, but probably to a lesser extent than the other leading pollutants.

Pollutants associated with AFOs can also originate from a variety of other sources, such as cropland, municipal and industrial wastewater discharges, urban runoff, and septic systems. The national analyses described in the following section are useful in assessing the significance of animal waste as a potential or actual contributor to water quality degradation across the United States.

^a AFOs are a subset of the agriculture category. Summaries of impairment by non-agricultural sources are not presented here.

^b Based on reports from 16 states.

Rank	Rivers	Lakes	Estuaries
1	Siltation (38%)	Nutrients (44%)	Pathogens (47%)
2	Pathogens (36%)	Metals (27%)	Oxygen-Depleting Substances (42%)
3	Nutrients (29%)	Siltation (15%)	Metals (27%)
4	Oxygen-Depleting Substances (23%)	Oxygen-Depleting Substances (14%)	Nutrients (23%)
5	Metals (21%)	Suspended Solids (10%)	Thermal Modifications (18%)

Source: USEPA (2000a).

Note: Percent impairment attributed to each pollutant is shown in parentheses. For example, siltation is listed as a cause of impairment in 38 percent of impaired river miles. Items in bold print are those commonly associated with animal feeding operations, although they are also associated with other sources. Figure totals exceed 100 percent because water bodies may be impaired by more than one source.

4.2 NATIONAL ANALYSES OF NUTRIENT CONTRIBUTIONS

The national contribution and importance of nitrogen and phosphorus from animal operations has been estimated in several analyses. The first two analyses (Sections 4.2.1 and 4.2.2) focus on the production of nitrogen/phosphorus (and therefore, the potential for animal waste to contribute to nutrient loadings in water), whereas the last analysis (Section 4.2.3) uses sophisticated modeling techniques to estimate the amount of nutrients that reach surface water due to disposal and use of animal manure.

4.2.1 1994 USGS Study on Nitrogen Production from Various Sources

USGS analyzed nitrogen sources (manure, fertilizers, point sources, and atmospheric deposition)¹² in 107 U.S. watersheds, and found that the proportion of nitrogen originating from each source differs according to climate, hydrologic conditions, land use, population, and physical geography (Puckett, 1994).

Exhibit 4-5 displays results of the analysis for selected watersheds using information from 1987. As shown, the production of manure nitrogen relative to other sources varies by watershed. The "manure" source estimates include waste from both confined and unconfined animals. Puckett (1994) does not address whether the proportion of waste from confined facilities is larger or smaller than the fraction from unconfined animals. In some cases, manure nitrogen is a large

¹²The analysis does not include other potentially significant sources of nitrogen, such as urban runoff, sewer overflows, septic systems, and contaminated ground water.

portion of the total nitrogen added to the watershed. In the following watersheds, more than 25 percent of nitrogen originates from manure:

- Trinity River, Texas
- White River, Arkansas
- Apalachicola River, Florida
- Altamaha River, Georgia
- Potomac River, District of Columbia
- Susquehanna River, Pennsylvania
- Platte River, Nebraska
- Snake River, Idaho
- San Joaquin River, California

As indicated by the wide distribution of these geographic areas, significant contributions of nitrogen from animal manure occur throughout the U.S.

Platte White Palouse Red River of River, River, River, the North, MN, ND Susquehanna River, PA Connecticut NE INWA River, CT Potomac River, DC Willamette River, Snake River, Tar River, NC San Joaquin Riv<u>er, CA</u> Altamaha River, GA **LEGEND** Nitrogen Source Point Sources Fertilizer Atmosphere Apalachicola River, FL Manure South Platte River, CO Trinity River, TX White River, AR

EXHIBIT 4-5
Proportions of Nitrogen Sources in Selected Watersheds (1987 Base Year)

Source: Puckett (1994). Note:

Note: CAFO point sources are included in the "manure" category.

4.2.2 1998 USDA Study of Nitrogen and Phosphorus Production Relative to Crop Uptake Potential

Because of its nutrient content, animal manure is a valuable crop fertilizer. However, if nutrients are applied in excess of amounts that can be used by plants, there may be a greater potential for releases to the environment. Based on data from the 1992 Census of Agriculture (USDC/Census Bureau, 1994), USDA evaluated the quantity of nutrients available from recoverable livestock manure relative to crop growth requirements, by county (Lander et al., 1998).¹³ The analyses are intended to reflect the amount of manure that can be recovered and utilized; the analyses therefore do not consider manure from unconfined animals.

Exhibits 4-6 and 4-7 show the estimated useable manure nitrogen and phosphorus production from confined livestock, including swine, chickens, turkeys, and cattle. The figures account for the inability to completely recover manure, as well as typical nutrient losses during storage and treatment. These losses can be significant, particularly for nitrogen, due to the high volatilization potential of ammonia. Considering typical management systems, average manure nitrogen losses range from 31 to 50 percent for poultry, 60 to 70 percent for cattle (beef, dairy, and other categories), and 75 percent for swine. By contrast, the typical phosphorus loss is 15 percent (Lander et al., 1998).

Exhibits 4-8 and 4-9 illustrate the potential for available manure nitrogen and phosphorus to meet or exceed plant uptake and removal in each of the 3,141 mainland counties, considering harvested non-legume¹⁵ cropland and hayland. (See Lander et al. [1998] for results of additional analyses which also consider legume cropland and pastureland.) Based on this analysis, available manure nitrogen exceeds crop system needs in 266 counties, and available manure phosphorus exceeds crop needs in 485 counties. The relative excess of phosphorus compared to nitrogen is not surprising, since manure is typically nitrogen-deficient relative to crop needs. Therefore, when manure is applied to meet a crop's nitrogen requirement, phosphorus is typically applied in excess of its crop requirement (Sims, 1995).

Several points underscore the magnitude of the problem. First, in several of the counties where animal manure nutrients exceeded crop capacities, excesses would occur even if manure were applied to all suitable land in those counties. In addition, county-wide nutrient balances likely

¹³County level data are not yet available for the 1997 Census. However, in Chapter 2, Exhibit 2-4 presents the national production of recoverable manure and nutrients generated by animal sector based on the 1997 Census data (USDA/NRCS, 2000; USDA/NASS, 1999).

¹⁴As noted earlier, volatilized ammonia can have significant impacts on air quality and water quality (via atmospheric deposition).

¹⁵Legumes (e.g., alfalfa, clovers, peas, and beans), through symbiotic biological nitrogen fixation, can "fix" atmospheric nitrogen gas into plant-available ammonia (Follett, 1995). Thus, legumes do not require nitrogen application.

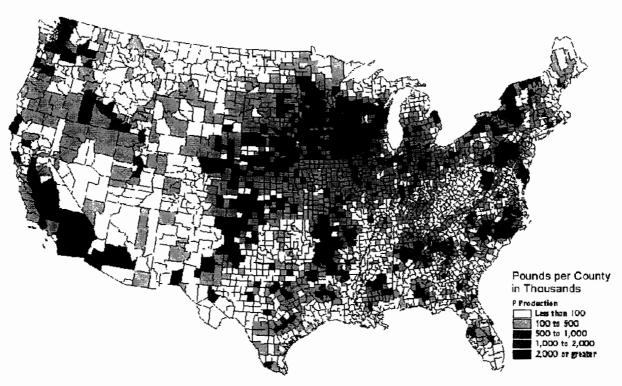
understate occurrences of local nutrient excesses, because most manure remains on the farm where it was generated, and confined animal production farms often do not have enough land to accommodate the manure (Letson and Gollehon, 1998). Specifically, large, specialized animal production farms typically have a relatively high animal/acre ratio when compared to smaller, integrated farms, as indicated by information on consolidation trends presented in Chapter 2. Information is not available on the number of AFOs that lease land for manure application or distribute the manure to others.

In a more recent evaluation of manure nutrients relative to the capacity of cropland to assimilate nutrients, USDA estimated that 1.5 billion pounds of farm-level excess manure nitrogen and 0.9 billion pounds of farm-level excess phosphorus were produced in 1997, representing about 60 percent of the recoverable manure nitrogen and 65 percent of the recoverable manure phosphorus. Excess farm level nutrients increased by more than 60 percent for both phosphorus and nitrogen between 1982 and 1997, and most were associated with large farms by 1997. For example, AFOs accounted for 64 percent of the excess nitrogen and 67 percent of the excess phosphorus in 1997 (Kellogg et al., 2000).

These USDA analyses are not intended to reflect actual manure management practices, but rather the *potential* for manure nutrient usage, without consideration of economic conditions, land ownership limitations, and other nutrient sources (e.g., commercial fertilizers). Additionally, the analyses do not account for environmental transport of applied manure nutrients. Therefore, an excess of nutrients does not necessarily indicate that a water quality problem exists; likewise, a lack of excess nutrients does not imply the absence of water quality problems. Nevertheless, the analyses are useful as a general indicator of excess nutrients on a broad-scale basis.¹⁶

¹⁶See Lander et al. (1998) for a complete list of assumptions and limitations.

EXHIBIT 4-7 Estimated Manure Phosphorus Production from Confined Livestock

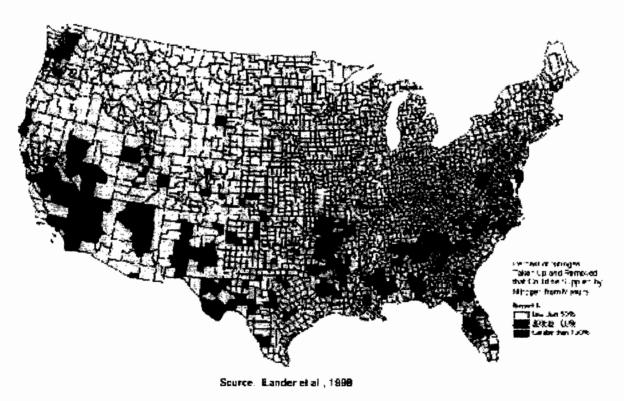


Source: Lander et al., 1998

Note: Manure phosphorus production includes recoverable manure phosphorus, after treatment/storage losses.

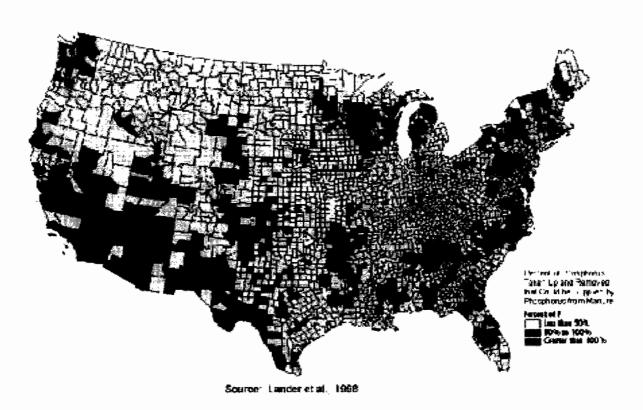
EXHIBIT 4-8

Potential for Nitrogen Available from Animal Manure to Meet or Exceed Uptake and Removal on Non-Legume, Harvested Cropland and Hayland



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EXHIBIT 4-9
Potential for Phosphorus Available from Animal Manure to Meet or Exceed
Uptake and Removal on Non-Legume, Harvested Cropland and Hayland



Note: Phosphorus available from animal manure includes recoverable manure phosphorus, after treatment/storage losses.

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4.2.3 1997 USGS Modeling Study of Nitrogen and Phosphorus Loadings to Surface Waters

The analyses described in Sections 4.2.1 and 4.2.2 are land-based and are not intended to represent in-stream water quality conditions. Delivery of nutrients to surface water is affected by many watershed characteristics, such as soil permeability, stream density, temperature, slope, and precipitation. Other watershed attributes, such as stream depth, stream velocity, and reservoir retention, further affect nutrient delivery along stream networks. USGS's SPARROW (SPAtially Referenced Regressions On Watershed attributes) water quality model accounts for these characteristics. SPARROW is a statistical method that relates measured water quality data to spatially referenced pollutant sources and watershed attributes. The model's regression equations express in-stream nutrient loads as a function of stream and land-surface characteristics. The equations incorporate point and non-point pollutant sources, as well as factors associated with material transport through the watershed (e.g., soil permeability and stream velocity). The model is used to describe spatial and temporal patterns in water quality and to identify factors and processes that influence those conditions (Smith et al., 1997).

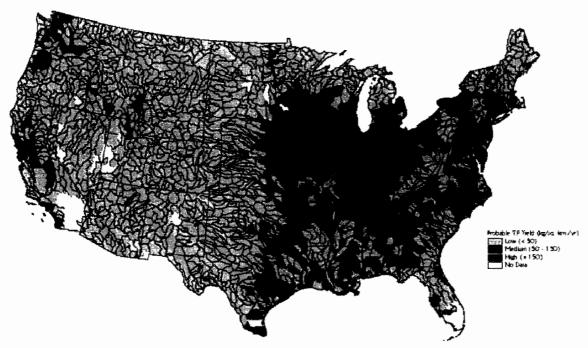
As described by Smith et al. (1997), USGS scientists applied the SPARROW model nationally to the 2,056 hydrologic cataloging units (watersheds) in the contiguous United States to estimate total nitrogen (TN) and total phosphorus (TP) export from various point and non-point sources (including commercial fertilizers, livestock waste, atmospheric nitrogen deposition, and non-agricultural land). Annual average livestock waste from both confined and unconfined animals was estimated for 1987, using data from the 1987 Census of Agriculture.¹⁷

Exhibits 4-10 and 4-11 present the predicted total local nitrogen and phosphorus yields (mass exported per unit of watershed area), from local (not upstream) sources. Exhibits 4-12 and 4-13 present the predicted percent contribution from animal waste to those local yields. The latter exhibits show that animal waste is a significant source (relative to other local sources) of instream nutrient concentrations in many watershed outlets, particularly in the central and eastern United States.

Smith et al. (1997) found that in general, commercial fertilizer contributes significantly more than livestock waste to local TN yield. By contrast, the analysis shows that livestock waste contributes more than commercial fertilizer to local TP yield. This may be due to the typically low N:P ratio in manure relative to crop N:P needs, which results in over-application of phosphorus when manure is applied to meet crop nitrogen requirements (Sims, 1995).

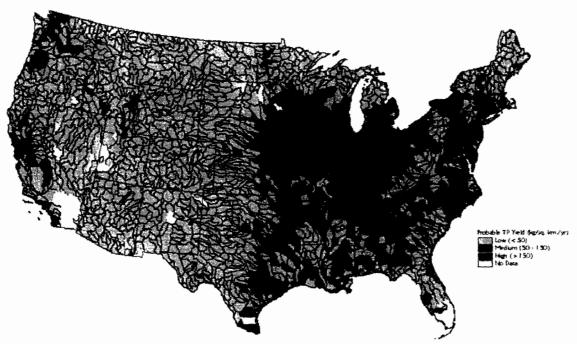
¹⁷Although CAFOs are designated as point sources in the Clean Water Act, they are included in the "livestock waste" category in this analysis. Point source data used in the analysis were obtained from a 1977 -1981 inventory (Smith et al., 1997).

EXHIBIT 4-10 Predicted Local Nitrogen Yield in Hydrologic Cataloging Units



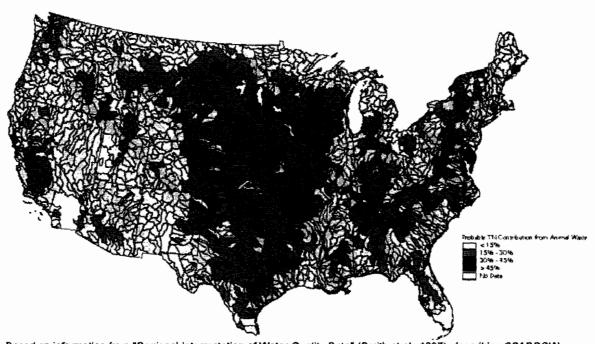
Based on information from "Regional Interpretation of Water Quality Data" (Smith et al., 1997), describing SPARROW model results for 1987 base year. "Local" refers to the within-HUC source contributions, independent of inflows from upstream watersheds. Other sources evaluated include point sources, commercial fertilizer, and nonagricultural land.

EXHIBIT 4-11
Predicted Local Total Phosphorus Yield in Hydrologic Cataloging Units



Based on information from "Regional Interpretation of Water Quality Data" (Smith et al., 1997), describing SPARROW model results for 1987 base year. "Local" refers to the within-HUC source contributions, independent of inflows from upstream watersheds. Other sources evaluated include point sources, commercial fertilizer, and nonagricultural land.

EXHIBIT 4-12
Predicted Percentage Contribution of Animal Waste to Local
Total Nitrogen Export from Hydrologic Cataloging Units



Based on information from "Regional interpretation of Water Quality Data" (Smith et al., 1997), describing SPARROW model results for 1987 base year. "Local" refers to the within-HUC source contributions, independent of inflows from upstream watersheds. Other sources evaluated include point sources, commercial fertilizer, atmospheric deposition, and nonagricultural land.

EXHIBIT 4-13
Predicted Percentage Contribution of Animal Waste to Local
Total Phosphorus Export from Hydrologic Cataloging Units



Based on information from "Regional Interpretation of Water Quality Data" (Smith et al., 1997), describing SPARROW model results for 1987 base year. "Local" refers to the within-HUC source contributions, independent of inflows from upstream watersheds. Other sources evaluated include point sources, commercial fertilizer, and nonagricultural land.

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4.3 NATIONAL ANALYSIS OF SHELLFISH BED IMPAIRMENT

In *The 1995 National Shellfish Register of Classified Growing Waters*, the National Oceanic and Atmospheric Association (NOAA) characterizes the status of 4,230 shellfish-growing water areas in 21 coastal states, reflecting an assessment of nearly 25 million acres of estuarine and non-estuarine waters. These waters support a significant amount of shellfish produced in the United States. Specifically, over 77 million pounds were harvested from these waters in 1995, with a commercial value of \$200 million (NOAA, 1997).

Results of this analysis are presented in Exhibit 4-14, which lists the number of shellfish beds impaired by feedlots, according to impairment classifications and estimated level of contribution. NOAA found that 3,404 shellfish areas had some level of impairment (i.e., a classification other than "approved" or "unclassified"). Of these, 110 (3 percent) were impaired to varying degrees by feedlots, and 280 (8 percent) were impaired by "other agriculture" (which could include land where manure is applied).

EXHIBIT 4-14 Shellfish Beds Impaired by Feedlots

	Level of Impairment (Harvest Classification)				Total
Estimated Level of Contribution from Feedlots	Conditionally Approved	Conditionally Restricted	Restricted	Prohibited	Impaired by Feedlots
Actual Contributor (High)	6	0	12	22	40
Actual Contributor (Medium)	3	1	16	23	43
Actual Contributor (Low)	2	1	2	9	14
Potential Contributor	1	0	8	4	13
TOTAL	12	2	38	58	110

Source: NOAA (1997).

4.4 LOCAL IMPACTS

This section presents documented local-level environmental incidents and impacts from animal feeding operations. The exhibits are organized by animal type and present information in three areas: (1) a listing of discharges directly to surface water revealing violations of the "no discharge" requirement; (2) human health related impacts; and (3) ecological, recreational, and other impacts. Exhibit 4-15 shows the organization of this information in the subsequent exhibits. Because this compilation resulted from a non-exhaustive literature search, it cannot be considered comprehensive. However, these exhibits show that a large number of events have been reported over time.

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EXHIBIT 4-15
Description of Environmental Incidents and Impacts Tables

Topic/Animal Category	Swine	Poultry	Beef and Dairy	Unspecified or Multiple
Listing of Discharges to Surface Water	Exhibit 4-16	Exhibit 4-19	Exhibit 4-22	Exhibit 4-25
	110 items	18 items	57 items	53 items
Human Health	Exhibit 4-17	Exhibit 4-20	Exhibit 4-23	Exhibit 4-26
Related Impacts	6 items	2 items	2 items	3 items
Ecological, Recreational, Other Impacts	Exhibit 4-18 50* items	Exhibit 4-21 9* items	Exhibit 4-24 9* items	Exhibit 4-27 28* items

^{*}Includes items from exhibits of discharge to surface water that indicated fish kills resulting from the discharge.

The relatively high number of reported surface discharges compared to fewer documented impacts probably reflects the higher visibility of the discharge events. Documenting environmental impacts from animal waste can be difficult, because as noted above, several manure constituents can also originate from other sources, and extensive investigations are sometimes required to estimate the relative contribution of each source. The events reported here are confined to impacts where AFOs were reported as a significant causative factor. Other contributing factors are identified to the extent that they were included in the literature. Examples of areas affected by animal waste are described in the following subsections.

Following Exhibits 4-16 through 4-27 are three examples that are discussed in more detail.

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
7/1/97	IL	Swine operation	800,000 gallons discharged	Contaminated drinking water of at least 5 homes with Escherichia coli; Illinois EPA levies fines totaling \$9,600 or more, which will partially fund creek restoration	Illinois Stewardship Alliance (1997) Macomb Journal (1999)
10/17/97	Clear Creek, IA	Swine operation	28,134 fish killed	\$4,000 direct cost + \$2,000 fine	Iowa Department of Natural Resources (1998)
10/9/97	Brooke Creek, IA	Swine operation	4194 fish killed	\$267.50 direct cost + \$2,500 fine	Iowa Department of Natural Resources (1998)
9/18/97	Prairie Creek, IA	Swine operation	93,403 fish killed	\$16,140.84 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
8/27/97	South Fork of Iowa River, IA	Swine operation	3,232 fish killed	\$264.23 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
7/26/97	Crane Creek, IA	3,200 head swine operation	109,172 fish killed	Blocked pipe resulted in discharge. \$33,882.73 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
9/4/96	North Buffalo Creek, IA	Swine operation	More than 100,000 gallons pumped into Creek; 586,753 fish killed	\$30,000 direct cost + \$3,000 fine	Iowa Department of Natural Resources (1998)
8/26/96	Rock Creek, IA	Swine operation	871 fish killed	\$237 direct cost	Iowa Department of Natural Resources (1998)
8/19/96	Cedar County, IA	Swine operation	3,676 fish killed	\$408.76 direct cost	Iowa Department of Natural Resources (1998)

EXHIBIT 4-16Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
8/19/96	Tipton Creek, IA	Swine operation	46,315 fish killed	\$3,908 direct cost + \$3,000 fine	Iowa Department of Natural Resources (1998)
11/15/95	Indian Creek, IA	Swine operation	4,928 fish killed	\$418 direct cost + \$3,000 fine	Iowa Department of Natural Resources (1998)
9/25/95	Williams Creek, IA	Swine operation	60,650 fish killed	\$21,436 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
7/23/95	Elk Creek tributary, IA	Swine operation	16,280 fish killed	\$1,410 direct cost + \$2,500 fine	Iowa Department of Natural Resources (1998)
7/20/95	Little Volga River, IA	Swine operation	23,416 fish killed	\$8,155 direct cost + \$1,500 fine	Iowa Department of Natural Resources (1998)
7/16/95	South Fork of Iowa River, IA	Swine operation	8,861 fish killed	\$6,000 direct cost + \$2,000 fine	Iowa Department of Natural Resources (1998)
7/1/95	Hamilton, IA	700 head swine operation	1.5 million gallons discharged; 8,800 fish killed	\$8,000 fine	Clean Water Action Alliance (1998)
3/28/95	South English River tributary, IA	Swine operation	Fish kill	\$4,000 fine	Iowa Department of Natural Resources (1998)
9/94	Kossuth County, IA	Swine operation	408 fish killed	\$73 direct cost + \$2,250 fine	Iowa Department of Natural Resources (1998)
9/94	Williams Creek, IA	Swine operation	Fish kill	\$2,000 fine	Iowa Department of Natural Resources (1998)
8/94	Otter Creek, IA	Swine operation	1,882 fish killed	\$968 direct cost	Iowa Department of Natural Resources (1998)

EXHIBIT 4-16 Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
5/94	Church Creek, IA	Swine operation	5,750 fish killed	\$2,118 direct cost	Iowa Department of Natural Resources (1998)
5/94	Hickory Creek tributary, IA	Swine operation	8,397 fish killed	\$722 direct cost + \$300 fine	Iowa Department of Natural Resources (1998)
3/94	Eagle Creek, IA	Swine operation	Fish kill	\$3,000 fine	Iowa Department of Natural Resources (1998)
12/93	Boone River, IA	Swine operation	Fish kill	\$5,000 fine	Iowa Department of Natural Resources (1998)
11/93	Union County, IA	Swine operation	Fish kill	\$1,000 fine	Iowa Department of Natural Resources (1998)
10/93	Middle Avery Creek, IA	Swine operation	Fish kill	\$9,700 fine split between operation and waste management design company	Iowa Department of Natural Resources (1998)
9/93	South English River tributary, IA	Swine operation	Fish kill	\$1,650 fine	Iowa Department of Natural Resources (1998)
7/93	Iowa River tributary	Swine operation	Fish kill	\$3,000 fine	Iowa Department of Natural Resources (1998)
6/93	Keokuk County, IA	Swine operation	Fish kill	\$4,500 fine	Iowa Department of Natural Resources (1998)
5/93	Brush Creek, IA	Swine operation	265,000 fish killed	\$10,000 direct cost + \$2,500 fine	Iowa Department of Natural Resources (1998)
4/93	Brookside Creek tributary, IA	Swine operation	Fish kill	\$2,000 fine	Iowa Department of Natural Resources (1998)

EXHIBIT 4-16 Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
4/93	Iowa River tributary, IA	Swine operation	Fish kill	\$300 fine	Iowa Department of Natural Resources (1998)
8/92	East Nishnabotna River, IA	Swine operation	Fish kill	\$1,000 fine	Iowa Department of Natural Resources (1998)
8/92	Tipton Creek, IA	Swine operation	34,994 fish killed	\$200 fine	Iowa Department of Natural Resources (1998)
7/92	Skunk River, IA	Swine operation		\$100 fine	Iowa Department of Natural Resources (1998)
7/92	South River, IA	Swine operation	6,264 fish killed	From land application of lagoon contents; effects lasted for 2 months. \$3,448 direct cost + \$19,500 fine	Iowa Department of Natural Resources (1998)
7/92	Wright County, IA	Swine operation	Fish kill	\$400 fine	Iowa Department of Natural Resources (1998)
3/92	Cedar River, IA	Swine operation		Retention basin overflow. \$250 fine	Iowa Department of Natural Resources (1998)
2/92	Beaverdam Creek, IA	Swine operation		Below-building pit overflow. \$300 fine	Iowa Department of Natural Resources (1998)
6/19/97	Renville County, MN	9,000 swine	100,000 gallons discharged; 690,000 fish killed	Lagoon overflow caused by timer malfunction. Fined for failure to notify.	Clean Water Action Alliance (1998)
8/96	Meeker County, MN	200 head swine operation	Overflowing lagoon		Clean Water Action Alliance (1998)
4/96	Blue Earth County, MN	500 head swine operation	Siphoned basin into a stream and had an un-permitted basin		Clean Water Action Alliance (1998)
4/96	Blue Earth County, MN	200 head swine operation	Siphoned pit/ un-permitted basin		Clean Water Action Alliance (1998)

EXHIBIT 4-16 Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
4/96	Nobles County, MN	Swine operation	Overflowing basin		Clean Water Action Alliance (1998)
4/96	Watonwan County, MN	700 head swine operation	Overflowing basin		Clean Water Action Alliance (1998)
2/96 - 4/96	Osborne Township, MN	Swine operation	Overflow from pit onto ground and into Rock River, at rate up to 12 gpm		Clean Water Action Alliance (1998)
10/95	Traverse County, MN	2,500 head swine operation	Overflowing pits		Clean Water Action Alliance (1998)
9/95	Lincoln County, MN	2,500 head swine operation	Pumped manure basin into a river		Clean Water Action Alliance (1998)
8/1/95	Lincoln, MN	Swine operation	5,000- 10,000 fish killed		Clean Water Action Alliance (1998)
5/95	Renville County, MN	700 head swine operation	Manure and contaminated wastewater flowed into a surface tile inlet in a county ditch		Clean Water Action Alliance (1998)
4/94 - 8/94	Lone Tree Township, MN	Swine operation	Pumped about 5,000 gallons of wastewater containing manure into a ditch every two weeks		Clean Water Action Alliance (1998)
4/94	Meeker County, MN	1,500 head swine operation	Multiple runoff problems		Clean Water Action Alliance (1998)
9/1/95	Gentry, MO	Swine operation	Unknown		NRDC (1995)
8/1/95	Greencastle MO	30,000 head swine operation	Over 20,000 gallons discharged; 173,000 fish killed		NRDC (1995)
8/96	Four-Mile Creek, NE	Swine operation	300-500 bullhead, 100 carp, 100 cyprinids killed	Lagoon discharge	Nebraska Department of Environmental Quality (1996)
6/95	Scholz Pond, NE	Swine operation	96 fish killed	Land application and pipeline break. \$13.25 direct cost + \$1,000 fine	Nebraska Department of Environmental Quality (1995b)
3/95	Swan Creek, NE	Swine operation	Fish kill	\$971.66 direct cost + \$10,000 fine	Nebraska Department of Environmental Quality (1995a)

EXHIBIT 4-16Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
2/1/97	Pamlico, NC	4,000 swine	1,000 gallon discharge	No noticeable fish kill	Leavenworth (1997)
8/1/95	Brunswick County, NC	6,400 head swine operation	2 million gallons discharged	6th major livestock discharge in 2 weeks	Warrick (1995a)
8/1/95	Onslow, NC	Swine operation	Under 1 million gallons discharged		Warrick (1995a)
7/1/95	Bladen, NC	Swine operation	1 million gallons discharged over 2 days		NRDC (1995)
6/1-21/95	New River, Onslow County, NC	10,000 head swine operation	25 million gallons discharged; 3,000-4,000 fish killed	\$110,000 fine, including \$6,200 for fish kill and \$92,000 in civil penalties	Meadows (1995); NRDC (1995); Warrick (1995b)
6/1/95	Sampson County, NC	Swine operation	1 million gallons discharged		NRDC (1995)
5/1/91	Duplin County, NC	Swine operation	"Tons of water" discharged		Stith and Warrick (1995)
12/10/96	West Branch Tontagony Creek, OH	Swine manure	Manure leaked into barn and into creek		Ohio Department of Natural Resources (1997)
10/10/96	Tributary to Beaver Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
09/03/96	West Branch Wolf Creek/Aldrich Run, OH	Swine manure	Manure ran off into ditch and into creek		Ohio Department of Natural Resources (1997)
35280	Tributary to Beaver Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
08/03/96	Tributary to Auglaize River (RM 87.75), OH	Swine manure	Liquid manure applied too heavily; runoff into tile		Ohio Department of Natural Resources (1997)
07/09/96	Little Tymochtee Creek, OH	Swine manure	Broken pipe on truck allowed manure to enter creek		Ohio Department of Natural Resources (1997)
05/17/96	Painter Creek, OH	Swine manure	Runoff from manure spreading		Ohio Department of Natural Resources (1997)

EXHIBIT 4-16 Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
02/27/96	Tributary to Pipe Creek, OH	Swine manure	Manure spread on fields, followed by snow melt and rain		Ohio Department of Natural Resources (1997)
12/06/95	Tributary to Stillwater River, OH	Swine manure	2,000,000 gallons pumped onto 54 acres		Ohio Department of Natural Resources (1997)
12/02/95	Little Tymochtee Creek, OH	Swine manure	Liquid manure pumped onto fields into tiles into creek		Ohio Department of Natural Resources (1997)
11/26/95	Leatherwood Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
10/25/95	Tributary to Spring Creek (RM 1.25), OH	Swine manure	Manure pumped onto fields, ran into tiles and to stream		Ohio Department of Natural Resources (1997)
10/20/95	Wolf Creek, OH	Swine manure	Unknown amount leaked from storage pit into stream		Ohio Department of Natural Resources (1997)
08/27/95	Indian Creek, OH	Swine manure	Lagoon pumped onto small field; drained into creek		Ohio Department of Natural Resources (1997)
34917	Indian Run, OH	Swine manure		Heavy rain after manure application to fields	Ohio Department of Natural Resources (1997)
07/03/95	Oak Run, OH	Swine manure	Accidental release from drain pipe during application		Ohio Department of Natural Resources (1997)
10/01/94	Second Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
09/24/94	Tributary to Lake Fork Mohican River, OH	Swine manure	Liquid manure entered field tile and creek		Ohio Department of Natural Resources (1997)
09/21/94	East Branch Salt Creek, OH	Swine manure	Swine fenced to stream, defecated on land - runoff to stream		Ohio Department of Natural Resources (1997)

EXHIBIT 4-16 Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
09/20/94	North Branch Salt Creek, OH	Swine manure	Swine fenced to stream, defecated on land - runoff to stream		Ohio Department of Natural Resources (1997)
09/11/94	Carter Creek, OH	Swine manure	800,000 gallons of manure applied to 8 acre field; discharged into tile into creek		Ohio Department of Natural Resources (1997)
05/31/94	Grog Run, OH	Swine manure	La goon drained via hose to field at edge of creek		Ohio Department of Natural Resources (1997)
07/15/93	Barcer Run, OH	Swine manure	Spray-irrigated manure ran off into stream		Ohio Department of Natural Resources (1997)
04/08/93	Tributary to Wabash River, OH	Swine manure			Ohio Department of Natural Resources (1997)
11/18/92	Tributary to Lick Creek, OH	Swine manure	Accidental discharge due to clogged pump		Ohio Department of Natural Resources (1997)
33841	Little Sugar Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
08/12/92	Tributary to Auglaize River, OH	Swine manure	Irrigated manure runoff into tile into creek		Ohio Department of Natural Resources (1997)
09/18/91	Salt Creek, OH	Swine manure	Manure washed into stream		Ohio Department of Natural Resources (1997)
08/24/90	Thompson Creek, OH	Swine manure	·		Ohio Department of Natural Resources (1997)
08/08/90	Bear Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
06/25/90	Cloverlick Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
06/13/90	Lees Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
05/01/90	Tributary to Caesar Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
09/27/89	Jennings Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
05/31/89	Grassy Fork, OH	Swine manure			Ohio Department of Natural Resources (1997)
04/28/89	Kale Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
32579	Wolf Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
11/15/87	Jennings Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
09/02/87	Mill Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
08/04/87	Painter Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
08/03/87	Camp Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
06/27/87	Buck Run, OH	Swine manure			Ohio Department of Natural Resources (1997)
05/21/87	Camp Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-16
Documented Discharges from Swine Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
05/05/87	Chapman Creek, OH	Swine manure			Ohio Department of Natural Resources (1997)
01/17/87	Unnamed creek, OH	Swine manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-17
Documented Human Health Related Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
1990	Delmarva Peninsula (DE, MD, VA)	Swine operation	Ammonium-nitrogen concentrations of 1,000 mg/L in shallow monitoring wells around swine waste lagoons	Scientific study	Ritter and Chirnside (1990)
4/98	Duplin County, NC	Swine operation	Ground water contamination	Nitrate levels five times state standards	The Associated Press (1998)
12/1/95	Four Oaks, NC	Swine operations	13 private wells contaminated		Warrick (1995e)
10/1/95	Shannon, NC	1,200 head swine operation	Family complains of overpowering stench and mist of manure when farmer sprays his fields		Warrick (1995d)
10/1/95	NC	Swine operation	4 private wells were found to have nitrate levels 10 times the health standard equal to the MCL of 10 mg/L	Linked conclusively to the swine operations	Warrick (1995c; 1995d)
4/1/95	Browntown, NC	Swine operations	Residents fighting with swine farmers over odor		Stith and Warrick (1995)

EXHIBIT 4-18 Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
1997	NC rivers	Swine operations	450,000 fish killed	Pfisteria piscicida outbreak	U.S. Senate (1997)
1985-1995	Sampson County, NC	Mainly swine (Livestock responsible for 93% of ammonia emissions across NC. Swine account for 78% of ammonia emissions from livestock operations in the southern coastal plain of NC, where Sampson County is located.)	100% increase in amount of ammonia in rainwater corresponds with growth of pork industry	Contributes to eutrophication via atmospheric deposition	Aneja et al. (1998)
9/1/95	NC	Swine	Zinc and copper in manure building to potentially harmful levels on fields	Zinc and copper added to feed	Warrick and Stith (1995)
9/1/95	Neuse River, NC	Swine	500,000 fish killed	Toxic dinoflagellate outbreak	Leavenworth (1995c)
6/13/95	Neuse River, NC	Swine	1 billion fish killed	Toxic dinoflagellate outbreak	Leavenworth (1995a)
1995	Coastal wetlands of NC	Swine operations	Closed shellfish beds		U.S. Senate (1997)
	NC	Swine	Low dissolved oxygen, fish kills, loss of submerged vegetation	Total Maximum Daily Load (TMDL) case study	USEPA (1999)
10/17/97	Clear Creek, IA	Swine operation	28,134 fish killed	\$4,000 direct cost + \$2,000 fine	Iowa Department of Natural Resources (1998)
10/9/97	Brooke Creek, IA	Swine operation	4194 fish killed	\$267.50 direct cost + \$2,500 fine	Iowa Department of Natural Resources (1998)
9/18/97	Prairie Creek, IA	Swine operation	93,403 fish killed	\$16,140.84 direct cost; fine was pending	Iowa Department of Natural Resources (1998)

EXHIBIT 4-18 Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
8/27/97	South Fork of Iowa River, IA	Swine operation	3,232 fish killed	\$264.23 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
7/26/97	Crane Creek, IA	3,200 head swine operation	109,172 fish killed	Blocked pipe resulted in discharge. \$33,882.73 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
9/4/96	North Buffalo Creek, IA	Swine operation	More than 100,000 gallons pumped into Creek; 586,753 fish killed	\$30,000 direct cost + \$3,000 fine	Iowa Department of Natural Resources (1998)
8/26/96	Rock Creek, IA	Swine operation	871 fish killed	\$237 direct cost	Iowa Department of Natural Resources (1998)
8/19/96	Cedar County, IA	Swine operation	3,676 fish killed	\$408.76 direct cost	Iowa Department of Natural Resources (1998)
8/19/96	Tipton Creek, IA	Swine operation	46,315 fish killed	\$3,908 direct cost + \$3,000 fine	Iowa Department of Natural Resources (1998)
11/15/95	Indian Creek, IA	Swine operation	4,928 fish killed	\$418 direct cost + \$3,000 fine	Iowa Department of Natural Resources (1998)

EXHIBIT 4-18 Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
9/25/95	Williams Creek, IA	Swine operation	60,650 fish killed	\$21,436 direct cost; fine was pending	Iowa Department of Natural Resources (1998)
7/23/95	Elk Creek tributary, IA	Swine operation	16,280 fish killed	\$1,410 direct cost + \$2,500 fine	Iowa Department of Natural Resources (1998)
7/20/95	Little Volga River, IA	Swine operation	23,416 fish killed	\$8,155 direct cost + \$1,500 fine	Iowa Department of Natural Resources (1998)
7/16/95	South Fork of Iowa River, IA	Swine operation	8,861 fish killed	\$6,000 direct cost + \$2,000 fine	Iowa Department of Natural Resources (1998)
7/1/95	Hamilton, IA	700 head swine operation	1.5 million gallons discharged; 8,800 fish killed	\$8,000 fine	Clean Water Action Alliance (1998)
3/28/95	South English River tributary, IA	Swine operation	Fish kill	\$4,000 fine	Iowa Department of Natural Resources (1998)
9/94	Kossuth County, IA	Swine operation	408 fish killed	\$73 direct cost + \$2,250 fine	Iowa Department of Natural Resources (1998)
9/94	Williams Creek, IA	Swine operation	Fish kill	\$2,000 fine	Iowa Department of Natural Resources (1998)

EXHIBIT 4-18Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
8/94	Otter Creek, IA	Swine operation	1,882 fish killed	\$968 direct cost	Iowa Department of Natural Resources (1998)
5/94	Church Creek, IA	Swine operation	5,750 fish killed	\$2,118 direct cost	Iowa Department of Natural Resources (1998)
5/94	Hickory Creek tributary, IA	Swine operation	8,397 fish killed	\$722 direct cost + \$300 fine	Iowa Department of Natural Resources (1998)
3/94	Eagle Creek, IA	Swine operation	Fish kill	\$3,000 fine	Iowa Department of Natural Resources (1998)
12/93	Boone River, IA	Swine operation	Fish kill	\$5,000 fine	Iowa Department of Natural Resources (1998)
11/93	Union County, IA	Swine operation	Fish kill	\$1,000 fine	Iowa Department of Natural Resources (1998)
10/93	Middle Avery Creek, IA	Swine operation	Fish kill	\$9,700 fine split between operation and waste management design company	Iowa Department of Natural Resources (1998)

EXHIBIT 4-18Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
9/93	South English River tributary, IA	Swine operation	Fish kill	\$1,650 fine	Iowa Department of Natural Resources (1998)
7/93	Iowa River tributary	Swine operation	Fish kill	\$3,000 fine	Iowa Department of Natural Resources (1998)
6/93	Keokuk County, IA	Swine operation	Fish kill	\$4,500 fine	Iowa Department of Natural Resources (1998)
5/93	Brush Creek, IA	Swine operation	265,000 fish killed	\$10,000 direct cost + \$2,500 fine	Iowa Department of Natural Resources (1998)
4/93	Brookside Creek tributary, IA	Swine operation	Fish kill	\$2,000 fine	Iowa Department of Natural Resources (1998)
4/93	Iowa River tributary, IA	Swine operation	Fish kill	\$300 fine	Iowa Department of Natural Resources (1998)
8/92	East Nishnabotna River, IA	Swine operation	Fish kill	\$1,000 fine	Iowa Department of Natural Resources (1998)

EXHIBIT 4-18
Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
8/92	Tipton Creek, IA	Swine operation	34,994 fish killed	\$200 fine	Iowa Department of Natural Resources (1998)
7/92	South River, IA	Swine operation	6,264 fish killed	From land application of lagoon contents; effects lasted for 2 months. \$3,448 direct cost + \$19,500 fine	Iowa Department of Natural Resources (1998)
7/92	Wright County, IA	Swine operation	Fish kill	\$400 fine	Iowa Department of Natural Resources (1998)
6/19/97	Renville County, MN	9,000 swine	100,000 gallons discharged; 690,000 fish killed	Lagoon overflow caused by timer malfunction. Fined for failure to notify.	Clean Water Action Alliance (1998)
8/1/95	Lincoln, MN	Swine operation	5,000- 10,000 fish killed		Clean Water Action Alliance (1998)
8/1/95	Greencastle MO	30,000 head swine operation	Over 20,000 gallons discharged; 173,000 fish killed		Clean Water Action Alliance (1998)
8/96	Four-Mile Creek, NE	Swine operation	300-500 bullhead, 100 carp, 100 cyprinids killed	Lagoon discharge	Nebraska Department of Environmental Quality (1996)
6/95	Scholz Pond, NE	Swine operation	96 fish killed	Land application and pipeline break; \$13.25 direct cost + \$1,000 fine	Nebraska Department of Environmental Quality (1995b)
3/95	Swan Creek, NE	Swine operation	Fish kill	\$971.66 direct cost + \$10,000 fine	Nebraska Department of Environmental Quality (1995a)

EXHIBIT 4-18 Documented Ecological, Recreational, and Other Impacts from Swine Operations

Date	Location	Source	Environmental Impact	Comments	Reference
6/21/95	New River, NC	Swine operation	25 million gallons discharged; 3,000-4,000 fish killed	\$6,200 direct cost + \$92,000 fine	Meadows (1995); Warrick (1995b)
6/1/95	Onslow County, NC	10,000 head swine operation	25 million gallons discharged; 3,000-4,000 fish killed	\$110,000 fine, including \$6,200 for fish kill and \$92,000 in civil penalties	NRDC (1995); Warrick (1995b)

EXHIBIT 4-19 Documented Discharges from Poultry Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
9/5/95	East Branch Beaverdam Creek, IA	Poultry operation	9,002 fish killed	\$839 direct cost + \$500 fine	Iowa Department of Natural Resources (1998)
10/1/91	Deep Run, MD	Poultry operation	10,000 fish killed		Maryland Department of the Environment (1987)
3/97	Grant County, MN	2,000 chicken poultry operation	Pumped waste into wetland		Clean Water Action Alliance (1998)
7/1/95	Duplin, NC	75,000 chicken operation	8.6 million gallons discharged; fish kill resulted		NRDC (1995)
02/04/97	Tributary to Town Run, OH	Poultry manure	Manure spread on frozen fields, followed by rainfall		Ohio Department of Natural Resources (1997)
10/22/96	Dahlinghaus Ditch, OH	Chicken manure	Manure entered field tiles and into stream		Ohio Department of Natural Resources (1997)
10/10/96	Dahlinghaus Ditch, OH	Chicken manure	Manure entered field tiles and into stream		Ohio Department of Natural Resources (1997)
07/15/96	Tributary to Beaver Creek, OH	Chicken manure	Manure entering stream from field tile		Ohio Department of Natural Resources (1997)
07/10/96	Dahlinghaus Ditch, OH	Chicken manure	Runoff from field application of manure		Ohio Department of Natural Resources (1997)
06/24/96	Little Chippewa Creek and Tributary, OH	Chicken manure	Manure runoff into ditch from farm (retention pond overflow)		Ohio Department of Natural Resources (1997)
03/20/95	Little Chippewa Creek	Chicken manure	Chicken manure possibly dumped into field tile		Ohio Department of Natural Resources (1997)
12/03/94	Kraut Creek, OH	Chicken manure	Manure entered field tile	Accidental removal of plank allowed manure to enter tile	Ohio Department of Natural Resources (1997)

EXHIBIT 4-19Documented Discharges from Poultry Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
9/13/94	Stillwater River, OH	Chicken manure	Manure entered tile, then stream		Ohio Department of Natural Resources (1997)
05/09/93	Henry Ditch, OH	Chicken manure		Approximately 4 miles affected in Indiana	Ohio Department of Natural Resources (1997)
08/14/92	Mississinewa River, OH	Chicken manure			Ohio Department of Natural Resources (1997)
11/03/91	Sugar Creek, OH	Chicken manure			Ohio Department of Natural Resources (1997)
09/13/90	Tributary to Blanchard River, OH	Chicken manure	Runoff from fields into creek		Ohio Department of Natural Resources (1997)
11/02/87	Powderlick Run, OH	Chicken manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-20 Documented Human Health Related Impacts from Poultry Operations

Date	Location	Source	Environmental Impact	Comments	Reference
1982	Sussex County, DE	1 .	Nitrate levels greater than 10 mg/L in 32 percent of wells		Chapman (1996)
	FL	Poultry operations	Nitrate levels greater than 10 mg/L in one-third of wells		Chapman (1996)

EXHIBIT 4-21 Documented Ecological, Recreational, and Other Impacts from Poultry Operations

Date	Location	Source	Environmental Impact	Comments	Reference
1997	Chesapeake Bay	Poultry operations	30,000 fish killed	Pfiesteria piscicida outbreak	U.S. Senate (1997)
	DE	Poultry industry	Eutrophication, fish kills and red tide	Not clear how much to attribute to poultry waste	Delaware's Center for the Inland Bays (1995)
8/97	Pokomoke River, MD	Poultry operations	20,000-30,000 fish killed	Pfiesteria piscicida outbreak; 13 humans also affected	Shields (1997)
6/20/95	Kings Creek, MD	Poultry operations	Fish kill	Pfiesteria piscicida outbreak	Shields and Meyer (1997)
6/19/95	MD	Poultry	Extensive fish kill in the Chesapeake Bay	Pfiesteria piscicida outbreak	New York Times (1997)
	Double Pipe Creek, MD	Poultry (700,000 chickens)	High fecal coliform counts	Threatens water supply as well as aquatic life and recreation	Gale et al. (1993)
1998	Tulsa, OK	Poultry (82.5 million chickens in the watershed)	Excessive algal growth in Lake Eucha; impacts on drinking water taste and odor	Tulsa spends \$100,000 per year to address taste and odor problems in the drinking water	Lassek (1998); Lassek (1997)
9/5/95	East Branch Beaverdam Creek, IA	Poultry operation	9,002 fish killed	\$839 direct cost + \$500 fine	Iowa Department of Natural Resources (1998)
10/1/91	Deep Run, MD	Poultry operation	10,000 fish killed		Maryland Department of the Environment (1987)

EXHIBIT 4-22 Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
3/1/98	Olmsted, MN	Dairy feedlot	125,000 gallons discharged	Contaminated local wells	Clean Water Action Alliance (1998)
7/97	Lyon County, MN	250 head cattle operation	runoff		Clean Water Action Alliance (1998)
5/97	Wabasha County, MN	Dairy operation	16,500 minnows and white suckers killed	Fish kill caused by ammonia.	Clean Water Action Alliance (1998)
4/97	Lyon County, MN	800 head cattle operation	Open lot runoff		Clean Water Action Alliance (1998)
3/97	LeSueur County, MN	1,960 head cattle operation	Overapplication and runoff		Clean Water Action Alliance (1998)
3/97	Lyon County, MN	1,000 head cattle operation	Open lot runoff		Clean Water Action Alliance (1998)
8/96	Nicollet County, MN	1,400 head cattle operation	Overapplication and runoff		Clean Water Action Alliance (1998)
6/96	Clay County, MN	500 head cattle operation	Multiple runoff culverts to river		Clean Water Action Alliance (1998)
4/96	Crow Wing, MN	100 head dairy operation	Stockpile runoff		Clean Water Action Alliance (1998)

EXHIBIT 4-22 Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
4/96	Houston County, MN	1,500 head cattle operation	Overflowing basin		Clean Water Action Alliance (1998)
11/95	Morrison County, MN	100 head cattle operation	Runoff to river		Clean Water Action Alliance (1998)
11/95	Olmsted County, MN	10,000 head cattle operation	Multiple runoff concerns		Clean Water Action Alliance (1998)
5/95	Slayton Township, MN	Steer operation	Runoff into a tributary of Beaver Creek		Clean Water Action Alliance (1998)
3/95	Lyon County, MN	400 head cattle operation	Tile inlet in feedlot		Clean Water Action Alliance (1998)
3/95	Lyon County, MN	2,000 head cattle operation	Runoff and unpermitted construction		Clean Water Action Alliance (1998)
4/94	LeSueur County, MN	1,000 head cattle operation	Multiple runoff concerns		Clean Water Action Alliance (1998)
4/94	Redwood County, MN	750 head cattle operation	Unpermitted basin and discharge		Clean Water Action Alliance (1998)
1985 - 1994	Tyrone Township, MN	950 steer cattle operation	Various problems, including massive runoff		Clean Water Action Alliance (1998)

EXHIBIT 4-22
Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
1/92	Green Isle Township, MN	Dairy operation	225,000 gallons of manure pumped onto a field in 5 hours, flowed through a drainage tile into Curran Lake		Clean Water Action Alliance (1998)
5/19/97	Tributary to Chickasaw Creek, OH	Cattle manure	Manure from cattle yard discharged to stream via tile		Ohio Department of Natural Resources (1997)
3/25/97	Prairie Outlet, OH	Cattle manure	Manure leached from holding ponds into creek		Ohio Department of Natural Resources (1997)
2/4/97	Tributary to Little Scioto River (RM 23.66), OH	Cattle manure	Manure spray gun malfunctioned and flooded field	***************************************	Ohio Department of Natural Resources (1997)
11/13/96	Scherman Ditch, OH	Cattle manure			Ohio Department of Natural Resources (1997)
10/27/96	Little Tymochtee Creek, OH	Cattle manure	Manure leaking from pit at dairy operation		Ohio Department of Natural Resources (1997)
9/30/96	Tributary to Coldwater Creek, OH	Cattle manure	Manure spread on fields ran into creek		Ohio Department of Natural Resources (1997)

EXHIBIT 4-22 Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
9/25/96	Tributary to Chickasaw Creek, OH	Cattle manure	Runoff from cattle feedlot into field tile into creek		Ohio Department of Natural Resources (1997)
8/13/96	Blacklick Creek, OH	Cattle manure	Manure sprayed on field ran into tile drain		Ohio Department of Natural Resources (1997)
7/15/96	Tributary to Beaver Creek, OH	Cattle manure			Ohio Department of Natural Resources (1997)
6/20/96	Threemile Creek, OH	Cattle manure	Runoff from field application of manure		Ohio Department of Natural Resources (1997)
5/23/96	Tributary to Pymatining Creek (RM 23.95), OH	Cattle manure	Runoff after spreading manure		Ohio Department of Natural Resources (1997)
5/22/96	Little Bear Creek, OH	Cattle manure	300,000 gallons of manure spread on fields, washed into creek		Ohio Department of Natural Resources (1997)
5/16/96	Tributary to Red Run, OH	Cattle manure	Manure spread directly into several ditches		Ohio Department of Natural Resources (1997)

EXHIBIT 4-22 Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
3/29/96	Tributary to Little Short Creek, OH	Cattle manure	Manure pumped into ravine and into stream		Ohio Department of Natural Resources (1997)
2/21/96	East Branch Sugar Creek, OH	Cattle manure		No fish kill; unsure if pollutants entered stream	Ohio Department of Natural Resources (1997)
1/9/96	Tributary to East Fork White Eyes Creek, OH	Cattle manure		No fish kill; unsure if pollutants entered stream	Ohio Department of Natural Resources (1997)
9/1/95	Indian Creek, OH	Cattle manure	600,000 - 800,000 gallons pumped onto 40 acres		Ohio Department of Natural Resources (1997)
8/20/95	Montezuma Creek, OH	Cattle manure	Sprinkling system to cool animals created excess runoff		Ohio Department of Natural Resources (1997)
8/19/95	Tributary to Anderson Fork, OH	Cattle manure	Tractor got stuck; manure tank emptied; rain washed manure into creek		Ohio Department of Natural Resources (1997)
7/10/95	East Fork White Eyes Creek, OH	Cattle manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-22
Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
5/3/95	Tributary to Killbuck Creek, OH	Cattle manure	Periodic discharges of manure to stream		Ohio Department of Natural Resources (1997)
5/3/95	Sugar Creek, OH	Cattle manure	Broken pipe at pit, manure flow into tile and then creek		Ohio Department of Natural Resources (1997)
12/5/94	Big Run, OH	Cattle manure	Runoff from pasture and feedlots		Ohio Department of Natural Resources (1997)
6/16/94	Harmon Brook, OH	Cattle manure	Crack in lagoon led to manure leak		Ohio Department of Natural Resources (1997)
12/15/93	Tributary to Grand Lake St. Mary's, OH	Cattle manure	Manure in ditch and tile leading to stream		Ohio Department of Natural Resources (1997)
8/20/93	Stony Creek, OH	Cattle manure	Runoff from feedlot entered creek		Ohio Department of Natural Resources (1997)
8/11/93	Middle Fork Sugar Creek, OH	Cattle manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-22
Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
7/12/92	Tributary to Black Fork Mohican River, OH	Cattle manure	Drainage from manure pit through field tile to creek		Ohio Department of Natural Resources (1997)
4/18/91	Tributary to Little Scioto River, OH	Cattle manure	Manure liquids ran off farm into ditch		Ohio Department of Natural Resources (1997)
2/20/91	Mohican River, OH	Cattle manure			Ohio Department of Natural Resources (1997)
8/20/90	Olentangy River, OH	Cattle manure			Ohio Department of Natural Resources (1997)
8/18/90	Tributary to Cowan Creek, OH	Cattle manure			Ohio Department of Natural Resources (1997)
8/16/90	Schenck Creek, OH	Cattle manure	Manure pit overflowed into ditch		Ohio Department of Natural Resources (1997)
6/16/90	Clear Creek, OH	Cattle manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-22 Documented Discharges from Beef and Dairy Operations to Surface Waters

Date	Location	Source	Description of Event	Comments	Reference
8/12/89	North Fork of Deer Creek, OH	Cattle manure			Ohio Department of Natural Resources (1997)
6/29/89	Painter Run, OH	Cattle manure			Ohio Department of Natural Resources (1997)
8/2/88	Tributary to Red Run, OH	Cattle manure			Ohio Department of Natural Resources (1997)
5/2/87	Big Run, OH	Cattle manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-23 Documented Human Health Related Impacts from Beef and Dairy Operations

Date	Location	Source	Environmental Impact	Comments	Reference
	WI	Dairy operation	Contamination of surface waters; ear and skin infections, as well as intestinal illnesses common to swimmers in manure- contaminated waterways		Behm (1989)
	Door County, WI	Dairy operations	Well contamination	State will spend \$3 million to protect Door County ground water. Families have had to drill new wells.	Behm (1989)

EXHIBIT 4-24 Documented Ecological, Recreational, and Other Impacts from Beef and Dairy Operations

Date	Location	Source	Environmental Impact	Comments	Reference
	Taylor Creek, FL	Dairy and beef operations	Eutrophication of Lake Okeechobee		Gale et al. (1993)
	Tillamook Bay, OR	Dairy operations	High f ecal coliform levels in the waters of the Bay	Affecting tourism and oyster industries. May be causing health hazards as well.	Gale et al. (1993)
6/18/95	Waco, TX	Dairy operations, as well as urban runoff and crop fertilization	An algal bloom of Anabaena, which caused a foul-smelling and -tasting chemical in water supplies		Wallace (1997)
6/16/95	Erath, TX	Dairy operations	Total N and P above screening levels in Upper North Bosque River		Pratt et al. (1997)
1991	Tierra Blanca Creek, TX	Cattle operations	Elevated sediment concentrations of copper and zinc; elevated aqueous concentrations of ammonia, chemical oxygen demand, chlorophyll <i>a</i> , coliform bacteria, chloride, conductivity, total Kjeldahl nitrogen, and volatile suspended solids	Relative contribution from various sources (e.g., runoff, lagoon discharges, leachate) was not assessed	USFWS (1991)
	Eau Claire, WI	Dairy operations	Swimming and water skiing are prohibited in Tainter Lake because of bacterial contamination	Sedimentation from development and crop runoff also causing problems	Behm (1989)
	Osh Kosh, WI	Dairy operations, as well as development	Algal blooms in Lake Winnebago	Lake Winnebago represents 17% of the state's water surface. City of Osh Kosh spends \$30,000 a year to kill algae.	Behm (1989)
	Black Earth Creek Watershed, WI	Dairy operations	Eutrophication		USGAO (1995a)
5/97	Wabasha County, MN	Dairy operation	16,500 minnows and white suckers killed	Fish kill caused by ammonia.	USGAO (1995a)

EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Description of Event	Comments	Reference
7/1/95	Fayette, IA		16,000 gallons discharged; 584 smallmouth bass, 22,011 minnows/ shiners killed		NRDC (1995)
7/1/95	Howard, IA		110 black bullheads, 16,000 minnows killed		NRDC (1995)
3/92	Hamilton County, IA	Swine, turkey, and dairy operation	Fish kill	\$1,000 fine	Iowa Department of Natural Resources (1998)
7/11/95	Tuscarora Creek, MD	Manure (ani mal type unknown)	1,000 fish killed		Maryland Department of the Environment (1987)
7/26/94	Toms Run, MD	Manure (ani mal type unknown)	1,500 fish killed		Maryland Department of the Environment (1987)
6/22/90	Wagram Creek, MD	Manure (animal type unknown)	19,000 fish killed		Maryland Department of the Environment (1987)
9/24/87	Farm Pond, MD	Manure (animal type unknown)	1,000 fish killed		Maryland Department of the Environment (1987)
3/30/87	Morgan Creek, MD	Manure (animal type unknown)	2,500 fish killed		Maryland Department of the Environment (1987)
7/30/86	Liitle Pipe Creek, MD	Manure (animal type unknown)	150 fish killed		Maryland Department of the Environment (1987)
7/15/86	Cabbage Run, MD	Manure (animal type unknown)	175 fish killed		Maryland Department of the Environment (1987)
9/30/85	Deep Run, MD	Manure (ani mal type unknown)	Hundreds of fish killed		Maryland Department of the Environment (1987)

EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Description of Event	Comments	Reference
9/29/85	Jennings Run, MD	Manure (animal type unknown)	3,900 fish killed		Maryland Department of the Environment (1987)
8/10/85	Deer Creek, MD	Manure (animal type unknown)	100,000 fish killed		Maryland Department of the Environment (1987)
1994	Belle River, MI	Manure (animal type unknown)	Fish kill	Overflow and misapplication of manure. \$5,150 direct cost + \$5,000 fine	Michigan Department of Environmental Quality
1994	Macon Creek, MI	Manure (animal type unknown)	Fish kill	Euipment failure caused manure discharge. \$1,330 direct cost + \$5,000 fine	Michigan Department of Environmental Quality
1994	Salt River, MI	Manure (animal type unknown)	Fish kill	Over-application of manure to field, causing runoff. \$20,000 direct cost + \$2,500 fine	Michigan Department of Environmental Quality
1993	Crockery Creek, MI	Manure (animal type unknown)		\$1,650 enforcement costs +\$2,500 fine	Michigan Department of Environmental Quality
1993	Deer Creek tributary, MI	Manure (animal type unknown)		\$4,000 enforcement costs + \$20,000 fine	Michigan Department of Environmental Quality
2/98	Lake Wagonga, MN	Manure (animal type unknown)	Manure-contaminated runoff discharged to lake	, , , , , , , , , , , , , , , , , , , ,	Clean Water Action Alliance (1998)
1/98	Nokasippi, MN	Manure (animal type unknown)	Manure-contaminated runoff (from feedlot and stockpile) discharged to river	Failed to notify authorities, made no attempt to abate or recover discharge	Clean Water Action Alliance (1998)
9/97	Blue Earth River, MN	Manure (animal type unknown)	Fish kill of 6,626 catfish, small-mouth bass, rock bass, white bass, and minnows		Clean Water Action Alliance (1998)

EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Description of Event	Comments	Reference
8/97	Hay Creek, MN	Manure (animal type unknown)	Fish kill of 6,000 brown trout and white suckers.		Clean Water Action Alliance (1998)
8/97	Speltz Creek, MN	Manure (animal type unknown)	300 gallons discharged; 130 minnows killed		Clean Water Action Alliance (1998)
6/97	Roseau County, MN	Manure (animal type unknown)	Manure discharge	Discharge from un-permitted tank, caused by improper construction and pump failure.	Clean Water Action Alliance (1998)
1996	Mankato, MN	Manure (animal type unknown)	Drained manure into Watonwan and Blue Earth Rivers		Clean Water Action Alliance (1998)
8/95 - 9/95	Larkin Township, MN	Various animals	3 weeks worth of overflow from lagoon through trench and into Kanaranzi Creek		Clean Water Action Alliance (1998)
7/95 - 8/95	Drammen Township, MN	Manure (animal type unknown)	Overflow of pits which drained into a ditch; 19,641 fish killed in Medary Creek		Clean Water Action Alliance (1998)
1994	Nicollet County, MN	Manure (animal type unknown)	Constant diversion of manure into streams from unknown facilities		Clean Water Action Alliance (1998)
6/96	Lost Creek, NE	Unclear if swine or cattle	2,120 fish killed	\$1,079.50 direct cost; fine was pending	Nebraska Department of Environmental Quality (1996)
10/28/96	Apple Ditch, OH	Manure	Manure coming from field tile		Ohio Department of Natural Resources (1997)
09/18/96	Tributary to Beaver Creek, OH	Manure			Ohio Department of Natural Resources (1997)
07/31/96	Montezuma Creek, OH	Cattle and swine manure	Manure entered stream from field tile		Ohio Department of Natural Resources (1997)

EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Description of Event	Comments	Reference
7/7/96	Cedar Fork, OH	Manure	Hose sprung leak and manure spread onto ground and into tile		Ohio Department of Natural Resources (1997)
07/05/96	Wabash River, OH	Manure	Manure runoff from milkhouse into field tile		Ohio Department of Natural Resources (1997)
07/04/96	Wabash River, OH	Cattle and swine manure	Runoff from field application of manure		Ohio Department of Natural Resources (1997)
06/17/96	East Fork Vermilion River, OH	Manure			Ohio Department of Natural Resources (1997)
10/26/95	Tributary to Mile Creek (RM 4.15), OH	Manure	Liquid manure applied too heavily		Ohio Department of Natural Resources (1997)
09/03/95	Tributary to Poplar Creek, OH	Manure	Accidental manure spill		Ohio Department of Natural Resources (1997)
08/24/95	Martins Creek, OH	Manure and milk products	Manure and milk washed into drains into creek		Ohio Department of Natural Resources (1997)
07/05/95	Rock Creek, OH	Manure			Ohio Department of Natural Resources (1997)
04/22/95	Newman Creek, OH	Manure			Ohio Department of Natural Resources (1997)
03/27/95	Kiber Run, OH	Cattle and swine manure	Runoff from spraying fields ran into field tiles		Ohio Department of Natural Resources (1997)
10/16/94	Prairie Creek, OH	Manure	Irrigated manure entered tile into creek		Ohio Department of Natural Resources (1997)
08/29/94	Tributary to Beaver Creek, OH	Cattle and swine manure	Crack in holding pit into tile		Ohio Department of Natural Resources (1997)

EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Description of Event	Comments	Reference
7/17/94	Black Run, OH	Manure			Ohio Department of Natural Resources (1997)
09/08/93	Little Beaver Creek, OH	Milkhouse wastewater and manure			Ohio Department of Natural Resources (1997)
09/09/92	Subtributary to Pawpaw Creek, OH	Cattle and swine manure	Possible runoff from feedlots		Ohio Department of Natural Resources (1997)
08/18/92	Tributary to Coldwater Creek, OH	Manure	Manure applied to field entered creek		Ohio Department of Natural Resources (1997)
07/08/92	Little Miami River, OH	Manure	Runoff and leachate into stream		Ohio Department of Natural Resources (1997)
04/29/91	Tributary to Bear Creek, OH	Manure	Manure entered field tile and into stream		Ohio Department of Natural Resources (1997)
03/02/91	Middle Fork Little Beaver Creek, OH	Manure			Ohio Department of Natural Resources (1997)
07/30/90	Sycamore Creek, OH	Manure and household wastes			Ohio Department of Natural Resources (1997)
11/09/89	Tributary to Beaver Creek, OH	Manure			Ohio Department of Natural Resources (1997)
08/19/89	Tributary to Jerome Fork, OH	Manure			Ohio Department of Natural Resources (1997)
08/07/89	Elkhorn Creek, OH	Manure			Ohio Department of Natural Resources (1997)
10/20/88	Indian Creek, OH	Manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-25
Documented Discharges to Surface Waters from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Description of Event	Comments	Reference
9/27/87	Big Run, OH	Manure			Ohio Department of Natural Resources (1997)
09/18/87	Spring Creek, OH	Manure			Ohio Department of Natural Resources (1997)

EXHIBIT 4-26
Documented Human Health-Related Impacts from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Environmental Impact	Comments	Reference
3/1/91	Des Moines, IA	Animal waste, as well as fertilizers	Contamination of drinking water with nitrate	Waterworks will spend \$5 million on a nitrate removal system	Hubert (1991)
6/15/95	Wichita, KS	Nutrients from farm runoff, including animal manure	Contamination of drinking water supply	Some algal strains growing in the reservoir are thought to produce a liver toxin linked to stomach flu. Wichita is installing a special filtering mechanism which will cost \$1 million per year to operate	Hays (1993)
	WI	Varied (including AFOs)	WI DNR estimates that 10% of the state's 700,000 wells exceed health standards	Major pollutant sources include CAFOs, development, crop farms, and ski slopes.	Behm (1989)

3

EXHIBIT 4-27
Documented Ecological, Recreational, and Other Impacts from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Environmental Impact	Comments	Reference
	Appoquinimink River, DE	Poultry, dairy, and beef	Eutrophication	Fish kills and hindered boating	Gale et al. (1993)
	GA, AL, FL	Animal waste	Excess nutrients in the Apalachicola-Chattahoochee- Flint watershed		USGS (1996)
6/15/95	KS	Feedlots, as well as farms	Eutrophication in Arkansas River	37 species of fish are in danger	Hays (1993)
1995	NC	Livestock waste	8-fold increase in ammonia emissions	Contributes to eutrophication via atmospheric deposition.	Leavenworth (1995b)
	Tar-Pamlico River Basin, NC		Eutrophication resulting in die- off of benthic life and toxic dinoflagellate growth	Winter algal blooms occur regularly. Shellfish beds have been closed because of fecal coliform.	North Carolina Division of Environmental Management (1995); USGAO (1995a)
	Nansemond-Chuckatuck watershed, VA	448,000 chickens 24,000 swine, 2724 beef cows, 125 dairy cows	Eutrophication and contamination with fecal coliform	Major source is runoff from agricultural areas. Shellfish areas have been closed.	Gale et al. (1993)
	WI	Excessive nutrients	90% decline in bass population in one year		Behm (1989)
7/1/95	Fayette, IA		16,000 gallons discharged; 584 smallmouth bass, 22,011 minnows/ shiners killed		NRDC (1995)
7/1/95	Howard, IA		110 black bullheads, 16,000 minnows killed		NRDC (1995)
3/92	Hamilton County, IA	Swine, turkey, and dairy operation	Fish kill	\$1,000 fine	Iowa Department of Natural Resources (1998)
7/11/95	Tuscarora Creek, MD	Manure (animal type unknown)	1,000 fish killed		Maryland Department of the Environment (1987)

EXHIBIT 4-27
Documented Ecological, Recreational, and Other Impacts from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Environmental Impact	Comments	Reference
7/26/94	Toms Run, MD	Manure (animal type unknown)	1,500 fish killed		Maryland Department of the Environment (1987)
6/22/90	Wagram Creek, MD	Manure (animal type unknown)	19,000 fish killed		Maryland Department of the Environment (1987)
9/24/87	Farm Pond, MD	Manure (animal type unknown)	1,000 fish killed		Maryland Department of the Environment (1987)
3/30/87	Morgan Creek, MD	Manure (animal type unknown)	2,500 fish killed		Maryland Department of the Environment (1987)
7/30/86	Liitle Pipe Creek, MD	Manure (animal type unknown)	150 fish killed		Maryland Department of the Environment (1987)
7/15/86	Cabbage Run, MD	Manure (animal type unknown)	175 fish killed		Maryland Department of the Environment (1987)
9/30/85	Deep Run, MD	Manure (animal type unknown)	Hundreds of fish killed		Maryland Department of the Environment (1987)
9/29/85	Jennings Run, MD	Manure (animal type unknown)	3,900 fish killed		Maryland Department of the Environment (1987)
8/10/85	Deer Creek, MD	Manure (animal type unknown)	100,000 fish killed		Maryland Department of the Environment (1987)
1994	Belle River, MI	Manure (animal type unknown)	Fish kill	Overflow and misapplication of manure. \$5,150 direct cost + \$5,000 fine	Michigan Department of Environmental Quality
1994	Macon Creek, MI	Manure (animal type unknown)	Fish kill	Equipment failure caused manure discharge. \$1,330 direct cost + \$5,000 fine	Michigan Department of Environmental Quality

EXHIBIT 4-27
Documented Ecological, Recreational, and Other Impacts from Operations with Unspecified or Multiple Animal Types

Date	Location	Source	Environmental Impact	Comments	Reference
1994	Salt River, MI	Manure (animal type unknown)	Fish kill	Over-application of manure to field, causing runoff. \$20,000 direct cost + \$2,500 fine	Michigan Department of Environmental Quality
9/97	Blue Earth River, MN	Manure (animal type unknown)	Fish kill of 6,626 catfish, small-mouth bass, rock bass, white bass, and minnows		Michigan Department of Environmental Quality
8/97	Hay Creek, MN	Manure (animal type unknown)	Fish kill of 6,000 brown trout and white suckers.		Michigan Department of Environmental Quality
8/97	Speltz Creek, MN	Manure (animal type unknown)	300 gallons discharged; 130 minnows killed		Michigan Department of Environmental Quality
7/95 - 8/95	Drammen Township, MN	Manure (animal type unknown)	Overflow of pits which drained into a ditch; 19,641 fish killed in Medary Creek		Michigan Department of Environmental Quality
6/96	Lost Creek, NE	Unclear if swine or cattle	2,120 fish killed	\$1,079.50 direct cost; fine was pending	Nebraska Department of Environmental Quality (1996)

4.4.1 Lake Eucha

Lake Eucha is located in the Lower Neosho Watershed in northeast Oklahoma. It is a major drinking water source for the city of Tulsa. Lake Eucha was included on the Oklahoma List of Impaired Waters for 1998 as a result of nutrients. Recently, there have been taste and odor problems in Tulsa's drinking water due to accelerated eutrophication (Lassek, 1998a; Front, 2000; Keyworth et al., 2000).

Officials estimate that approximately 750 chicken houses are located within the lake's watershed, each containing about 110,000 birds (Lassek, 1998b). In the Lake Eucha basin, a popular method of fertilizing permanent pasture is the surface application of poultry litter. Litter is highly effective, due to its high content of nutrients (nitrogen, phosphorus, and potassium) and organic matter. However, if not properly managed, these nutrients could reach surface water and cause eutrophication and consequently, algae blooms (Neal and Storm, 1999).

Detailed monitoring of Lake Eucha in 1997 showed that the algae balance was typical of eutrophic lakes. In addition, although the lake was free of harmful bacteria (an indicator of possible impacts from animal waste), excessive bacteria were found in the tributaries. This study, by the Oklahoma Conservation Commission, linked phosphorus from poultry waste runoff to excessive algae growth in the lake (Wagner and Woodruff, 1997; Lassek, 1998a). The algae causes taste and odor problems in the water, costing Tulsa thousands of dollars for treatment (Lassek, 1998a; Front, 2000).

The Oklahoma legislature has announced that drinking water contamination due to CAFOs is a priority issue to be addressed. Studies are being conducted at Oklahoma State University and Texas A&M University to determine limiting nutrients in Lake Eucha tributaries. These studies will be used in combination with other ongoing research to develop a total maximum daily load (TMDL) for Lake Eucha (Keyworth et al., 2000). In addition, the city of Tulsa is working to design a land conservation plan to address the problem (Front, 2000). Tulsa has also begun to buy land around Lake Eucha in an effort to create a buffer zone for the city's drinking water supply (Lassek, 1998b).

4.4.2 The Chino Basin

The Santa Ana River watershed has the highest density of dairy cows in the nation, averaging 25-30 cows per acre. Currently, 270 dairies operate on 25,000 acres within the Chino Basin portion of the watershed, with over 336,000 animals. Although the number of dairies continues to decrease, the number of animals is increasing, and the resulting impact on water quality is enormous. The 1998 California 303(d) List and Total Maximum Daily Load (TMDL) Priority Schedule issued by the EPA for the Chino Basin area cites agriculture and the dairies as the source of significant impairment to surface waterbodies due to nutrients, pathogens, suspended solids, salinity, total dissolved solids (TDS), and chlorides (OCWD, 2000).

Accumulation of salts and nitrates in the Chino Basin is occurring as a result of stockpiling manure and runoff from dairy waste. The Santa Ana River and the ground water basin it recharges supply over 2 million residents with approximately 75 percent of their water. The impact of large-scale dairies on recharge water quality is a critical issue in protecting Orange

County's primary drinking water supply. The Orange County Water District (OCWD), along with other concerned water agencies, has dedicated considerable resources to remove salts and nitrates from the Orange County ground water basin in order to improve the quality of water. Projects completed or in the construction phase that are directed at the removal of salts and nitrates include:

- Santa Ana River Interceptor (SARI) \$100 million
- SARI Extension to Lake Elsinore \$25 million
- Arlington Desalter (Riverside) \$13.5 million
- Water Factory 21 (Fountain Valley) \$20 million
- Chino Desalter \$39 million
- 7th Street Desalter (Tustin) \$7 million
- Prospect Desalter (Tustin) \$3 million
- Garden Grove Nitrate Reduction \$2 million

Efforts are currently underway at OCWD on two additional projects aimed at reduction of salts and nitrates. The proposed Ground Water Replenishment System (GWRS) is a \$350 million proposed project that will utilize microfiltration and reverse osmosis to desalt treated wastewater, which will be transported to ground water recharge basins to significantly lower the basin's salt levels. The Irvine Desalter is a \$30 million project to extract and remove salts from ground water for use in the Irvine area (OCWD, 2000).

4.4.3 Lake Waco and the Bosque River Watershed

Lake Waco is located in the Bosque River watershed in Texas. It is the public water supply for the city of Waco and several adjoining communities. In 1996, 23 river or lake segments caused concern or possible concern for six different criteria, including over 40 percent (19 instances) caused by nutrients (Texas Office of Water Resource Management, 1997). In 2000, water quality testing showed high levels of nutrients in the North Bosque River (Segment 1226) and in the Upper North Bosque River (Segment 1255). These high levels have contributed to excessive growths of algae and other aquatic plants, which can cause taste and odor problems in drinking water and result in fish kills under certain circumstances. High levels were also found for chloride, sulfate, total dissolved solids, and occasionally, bacteria (TNRCC, 2000a). The elevated level of bacteria was found to correlate with dairy waste application fields and herd density (TIAER, 1998).

The Upper North Bosque River (Segment 1255) is located in Erath County. Erath County is home to a large dairy industry, which has become increasingly concentrated over the last few decades. These dairy operations produce over 1.5 million tons of waste per year (PEER, 2000). A judge in upstream Erath County requested a waste management study for the county's dairy industry, which generates over 1 million cubic yards of dry-state dairy manure per year. The application of dairy waste to fields resulted in non-point nutrient runoff into the Bosque River during storm events, resulting in degraded water quality (Brazos River Authority, 1998). The state of Texas has a TMDL goal of reducing annual average soluble phosphorus loading by about 50 percent. The draft TMDL for the North Bosque River is due to be published this fall (TNRCC, 2000a).

In public comment on the 2000 Texas Clean Water Act Section 303(d) List, a representative of the National Wildlife Federation contended that there were taste and odor problems in Lake Waco and that these are due to algae. The Texas Natural Resource Conservation Commission (TNRCC) response to the comment notes that the TMDL currently being developed for the North Bosque River is expected to significantly reduce nutrient loading to Lake Waco. This may address the periodic taste and odor problem in Lake Waco if it is caused by algae (TNRCC, 2000b).

4.5 CASE STUDY SUMMARY

Over 100 case studies were compiled and presented in a summary report titled "Case Study Summary: Manure Application" (USEPA, 2000b). This report is included in the public record.

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5. EFFECTS OF THE PROPOSED REGULATIONS

5.1 POTENTIAL BENEFITS FROM POLLUTANT REDUCTIONS

The main sources of pollution from CAFOs include:

- waste, runoff, and leachate from confinement facilities and manure storage piles;
- runoff and leachate from land application sites;
- discharges and leachate from storage lagoons; and
- airborne emissions from confinement facilities, land application sites, and storage.

The practical impacts of implementing the proposed regulations are a function of the following: (1) the location and characteristics of affected facilities; (2) current waste and runoff management practices; and (3) the contribution of pollutants from other sources.

In general, increased treatment and management practices can reduce environmental impacts and subsequent human health effects from animal waste. They can also maximize the use of animal waste as a fertilizer. Exhibit 5-1 presents the main environmental benefits that could arise from the treatment and management of animal waste.

The EPA is not currently able to quantitatively evaluate all human health and ecosystem benefits associated with water quality improvements from reduced releases of CAFO wastes. The EPA is even more limited in its ability to assign monetary values to those benefits. The economic benefit analysis can be found in the benefit report, titled "Environmental and Economic Benefits of the NPDES/ELG CAFO Rules" and located in section 9.5 of the public record.

In some cases, animal waste releases to the environment result in direct monetary costs. Many of these costs are associated with additional requirements for drinking water treatment. For example, in California's Chino Basin, it could cost over \$1 million per year to remove the nitrates from drinking water due to loadings from local dairies (USEPA, 1993b). In Iowa, Des Moines Water Works planned to spend approximately \$5 million to install a treatment system to remove nitrates from their main sources of drinking water, the Raccoon and Des Moines Rivers (Hubert, 1991). Agriculture was cited as a major source of the nitrate contamination, although the portion attributable to animal waste is unknown. In Wisconsin, the city of Oshkosh has spent an extra \$30,000 per year on copper sulfate to kill the algae in the water it draws from Lake Winnebago (Behm, 1989). The thick mats of algae in the lake have been attributed to excess nutrients from manure, commercial fertilizers, and soil.

EXHIBIT 5-1 Anticipated Benefits of the CAFO Proposed Regulations

Category	Benefit	Origin of Impact	Population/Resources Affected	Notes
Human Health	Reduced risk of methemoglobinemia ("blue baby syndrome")	Nitrates in drinking water in excess of the MCL (Maximum Contaminant Level) of 10 mg/L	Primarily infants drinking water not treated by public treatment facilities (private rural wells; ground water is more susceptible than surface water)	Nitrate is extremely mobile in the environment, and nitrate contamination of ground water is a well-recognized historical problem in the agricultural community. According to the EPA's National Survey of Pesticides in Drinking Water Wells (1990), nitrate is the most widespread agricultural contaminant in drinking water wells. The EPA estimates that 4.5 million people are exposed to nitrate levels in excess of the MCL.
Human Health	Avoided illness from pathogenic organisms (e.g., gastrointestinal illness; infections of the skin, eye, ear, nose, or throat)	Pathogens in drinking and recreational waters	People drinking or swimming in contaminated water. Surface waters, and ground waters in sandy or fractured soils, are most susceptible to contamination.	Over 150 pathogens in manure are linked to human risk (e.g., Salmonella, Cryptosporidium parvum, Giardia lamblia, Escherichia coli). A U.S. General Accounting Office study (1997) of bacterial contamination of ground water over a four-year period found contamination in 3 to 6 percent of community water systems each year, and 15 to 42 percent of private wells. Drinking water disinfection does not eliminate the need for source water protection; source water protection is an integral part of the multiple barrier approach to drinking water treatment. Drinking water disinfection also does not address recreational risks.
Human Health	Avoided illness from toxic aquatic organisms (e.g., red tides, <i>Pfiesteria piscicida</i>)	Toxic organisms whose growth is enhanced by eutrophication (nutrient enrichment)	People with significant dermal or inhalation exposure to affected estuarine/marine waters; people consuming affected shellfish (pathways vary by organism)	

EXHIBIT 5-1 Anticipated Benefits of the CAFO Proposed Regulations

Category	Benefit	Origin of Impact	Population/Resources Affected	Notes
Ecological, Recreational	Avoided fish kills and other environmental damage (e.g., fish and wildlife disease, clogged fish gills, benthic habitat destruction, eutrophication) due to discharges of waste directly to surface water	BOD, ammonia, pathogens, solids, nutrients	Surface waters, aquatic organisms, waterfowl, people using the water for recreation	States have documented hundreds of cases of discharges from CAFOs, resulting in the death of millions of fish, over the past decade. Discharges directly to surface water are prohibited by the existing effluent guidelines except in the event of the 25-year, 24-hour storm, but implementation of the guidelines has been problematic. The proposed regulations are likely to call attention to the problem of such discharges and result in improved implementation. The proposed regulations also expand the scope of regulatory coverage and establish operation and maintenance requirements for storage lagoons to reduce the likelihood of discharge.
Ecological, Recreational	Reduced contribution to eutrophication effects (harmful algae blooms, decreased dissolved oxygen, fish kills, reduced biodiversity, reduced abundance of desirable aquatic plants) due to runoff from land application sites	Nutrients	Surface waters, aquatic organisms, people using the water for recreation	The EPA's National Water Quality Inventory (1997) indicates that nutrients are the leading cause of impairment of U.S. lakes and rivers and are the fifth leading cause of impairment of U.S. estuaries.
Ecological, Recreational	Reduced contribution to environmental damage due to runoff of other (non- nutrient) pollutants from land application sites	BOD, pathogens, solids, salts, metals	Surface waters, aquatic organisms, waterfowl, people using the water for recreation	The proposed regulations' CNMP requirement focuses on nutrients but would also incidentally address other pollutants.

EXHIBIT 5-1 Anticipated Benefits of the CAFO Proposed Regulations

Category	Benefit	Origin of Impact	Population/Resources Affected	Notes
Commercial	Reduced damage to commercial fishing and shellfish industries	Nutrients, BOD, pathogens, solids	Commercial fishing and shellfish industries	The National Oceanic and Atmospheric Administration (1995) reported that feedlots were a potential or actual contributor to the impairment of 110 shellfish beds (3 percent of all impaired shellfish areas). Outbreaks of <i>Pfiesteria</i> have directly impacted menhaden (a commercially harvested fish), and indirectly impacted the commercial fishing industry as a whole. Nutrient enrichment is one of several factors that affect growth of <i>Pfiesteria</i> . Reduction in submerged aquatic vegetation (SAV) due to excessive algae and suspended solids is a significant impact because SAV serves as critical habitat for juvenile fish and crabs. The proposed regulations' CNMP requirement focuses on nutrients but would also incidentally address other pollutants.
Other	Avoided costs associated with treatment or replacement of nitrate-contaminated ground water	Nitrates in drinking water in excess of the MCL of 10 mg/L	Public and private drinking water sources (ground water is generally more susceptible than surface water)	By implementing the proposed regulations, the following treatments may be avoided: private well owners needing to drill deeper wells to reach uncontaminated ground water or purchase bottled water, and public water suppliers needing to obtain an uncontaminated source or treat the water to meet the MCL.
Other	Avoided costs associated with treatment to remove algae, odors, and disinfection byproducts from drinking water	Algae growth stimulated by nutrients	Drinking water sources (surface water)	Implementing the proposed regulations may decrease the amount of disinfection byproducts (e.g., trihalomethanes) in drinking water that exceed the MCL. Disinfection byproducts are caused by chlorination of organic matter. The guidelines would also decrease additional or alternative treatment required to avoid or remove excess byproducts.

5.2 REPORTED BENEFITS OF ANIMAL WASTE MANAGEMENT AND RELATED NON-POINT SOURCE MEASURES IN SELECTED WATERSHEDS

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Several states have successfully implemented non-point source pollution programs under Section 319 of the Clean Water Act. Following are descriptions of the reported benefits derived from some of these programs and summaries of other research on specific land application practices. The examples provide anecdotal evidence of the effectiveness of animal waste management measures that might be implemented as a result of the proposed regulations. Several of the examples demonstrate the impact of a single management practice (e.g., dry litter waste management), while others address comprehensive plans that may include several practices.

5.2.1 Benefits of Single Practices

The effects of riparian forest restoration, dry litter waste management, dead bird composting, and land application practices are discussed below. All examples except the land application practices are described in *Section 319 Success Stories Volume II: Highlights of State and Tribal Nonpoint Source Programs* (USEPA, 1997b). Land application practices were investigated by Daniel et al. (1995). Studying the effects of separate practices individually leads to a better understanding of the impact associated with each of these practices and whether each would be a useful component of comprehensive management plans.

Riparian Forest Restoration

In the Suwanee River basin near Tifton, Georgia, in the Southeastern Coastal Plain, a riparian forest (trees, shrubs, and native grasses) was reestablished to ameliorate the water quality impacts of liquid manure application to cropland. Project workers evaluated the effects of the riparian restoration by measuring changes in the surface and subsurface water quality indicators in the field where manure was applied and again after the runoff had moved through the restored riparian area toward the stream. The monitoring results demonstrated that the restored riparian area effectively removed nitrogen, phosphorus, and sediment in the first two years of the project. Furthermore, nitrate levels leaving the area in shallow ground water not exposed to the riparian forest were higher than in mature riparian forest sites.

Dry Litter Waste Management

At a swine farm in Hawaii, a modified dry litter waste management system was implemented to lessen water quality impacts. In the dry system, swine are housed in sloping pens. Dry litter or bedding is used to help push the waste down the slope into a composting or storage pit, rather than using water to transport the waste.

The Hawaiian farm improved the dry system by incorporating pen sizes with slopes ranging from 15:1 to 20:1. Wood chips and grass cuttings were found to be excellent bedding materials, but the farm achieved best results with macadamia nut husks. The swine crush the bedding materials and the manure with their hooves; the mix dries and begins to decompose, and eventually moves down slope into a composting pit. The composted product is a good medium for organic farming, and can be used to generate income for the swine farmer. The product can be sold in

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Hawaii for about \$30 per cubic yard. A typical pen can convert about 30 cubic yards of green waste into 20 cubic yards of compost annually.

In addition to helping protect water quality by eliminating lagoons, the dry litter waste management system also produces very little odor. Hydrogen sulfide (H₂S) levels recorded throughout the production and storage areas were considerably less than the conventional wash down system. H₂S measurements at the dry litter facility were 10.7 parts per billion (ppb) in the production area and 5.0 ppb in the storage area. By comparison, H₂S levels at the control or conventional wash down facility were 54.3 ppb in the production area and 104.5 ppb at the entry to the waste lagoon.

Dead Bird Composting

In 1993, 62 growers in a six-county area in south central Mississippi handled 7 million birds. By 1997, 150 growers reported a census of 16.2 million birds. Because of this expansion, the state was concerned about potential threats to surface and ground water resources from dead birds, which traditionally were disposed in burial pits or incinerated. Arkansas recently prohibited the use of pits for dead bird disposal, because the carcasses often decay only partially and the leachate from the pits poses a danger to surface water and ground water.

The project promotes composting as a preferred method of dead bird disposal. Approximately 194,400 birds per year will be disposed of by composting in a manner that reduces the chance of ground water contamination. In addition, area farmers are saving up to \$25 per ton by using the composted material as a substitute for commercial fertilizer. (When composting is combined with other practices such as soil testing and nutrient management planning, it reduces the risk of nutrient enrichment to nearby surface waters.)

Land Application Practices

Daniel et al. (1995) applied animal manure to constructed plots with established grass and measured the resulting impacts on the quality of runoff and subsurface water. The study investigated the effect of differing application rates and other factors on the runoff of the following animal waste constituents: total Kjeldahl nitrogen, ammonia-nitrogen, nitrate-nitrogen, total phosphorus, orthophosphorus, total suspended solids, and chemical oxygen demand.

The results of the study indicate that lower application rates resulted in lower runoff for all constituents from poultry litter, and lower runoff of all constituents except nitrate-nitrogen from both poultry and swine manure. Lower application rates were also associated with less nitrate leaching into subsurface water.

5.2.2 Benefits of Multiple Practices

The following examples demonstrate the effect of multiple practices available to farmers. These examples are all taken from USEPA (1997b).

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Cadron Creek, Arkansas

The Cadron Creek Watershed in Arkansas has a high concentration of poultry and dairy farms. Cadron Creek is widely used for recreation, canoeing, and fishing; Brewer Lake provides drinking water to the cities of Morrilton and Conway. Other land uses in the project area include forestry (41 percent), grasslands (52 percent), and croplands (6 percent).

All waters within the watershed are threatened by bacteria and nutrients from confined animal operations. At least 20 stream miles do not meet their designated uses, and it is likely that most small streams in the watershed do not meet the standard for contact recreation.

To restore the watershed, the Van Buren County Conservation District implemented a portable land application system for liquid animal waste, which collects and redistributes liquid waste from 30 to 40 dairies to return nutrients to pastures and fields in the watershed and reduce pollution in surface waters and ground water. Other key elements of the project include monitoring on two creeks and establishing on-farm waste management systems. Farmers are applying the following best management practices (BMPs):

- dead poultry composting;
- nutrient management planning;
- pasture management;
- proper grazing use;
- · waste management systems; and
- waste management ponds.

Water quality monitoring indicates that these systems successfully reduced nutrient and bacteria loading to Ward Creek in this watershed. For example, fecal coliform bacteria levels in the stream decreased by a factor of 10 (from 100,000 to 10,000 colonies per 100 ml). The count is still far higher than the 200 colonies per 100 ml standard for recreational contact; however, with continued efforts, the project is anticipated to restore swimming as a beneficial use of this stream.

Benthic macroinvertebrate communities (aquatic insects) are another indicator of watershed health and in-stream conditions. Species diversity, a standard indicator of benthic community strength, is measured on the Family Biotic Index (FBI): the lower the FBI, the more diverse the community. The FBI in the monitored stream improved from 5.48 (which indicates the probability of substantial organic pollution) to 4.27 (which indicates the probability of slight organic pollution).

Moore's Creek and Beatty Branch Subwatershed, Arkansas

The Moore's Creek and Beatty Branch subwatershed is part of the Muddy Fork Hydrologic Unit Area in northwestern Arkansas. The Muddy Fork Hydrologic Unit Area encompasses 47,122 acres, the tributaries of the Illinois River and Lakes Lincoln, Budd Kidd, and Prairie Grove. These tributaries form Lincoln Lake, a drinking water reservoir serving the city of Lincoln.

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The project implemented under Section 319 began with a monitoring project in these waters to help establish the usefulness of nutrient BMPs. Land uses, primarily poultry production and pasture management, are major sources of nutrients and chronic high turbidity. According to the state's 1996 Water Quality Inventory Report, water in the area only partially supports aquatic life. Pathogen indicators sampled in the Muddy Fork Hydrologic Unit Area also exceed acceptable limits for primary contact recreation. This problem, reported in the 1994 water quality inventory, was traced to extensive poultry, swine, and dairy operations in the Moore's Creek basin. Essentially, all parts of the subwatershed are affected by these activities.

Nitrogen and phosphorus management practices were applied throughout the basin to help control the flow of nutrients from CAFOs. Specifically, BMPs were used on approximately one half of the pasture land along Moore's Creek and two-thirds of the pasture land along Beatty Creek. Five monitoring sites were established on Moore's Creek and Beatty Branch to demonstrate the integrated impact of the nutrient BMPs on water quality. Random samples were collected at all five sites, and storm-event samples were also collected at two sites.

Monitoring during the first three years of the project (1991 to 1994) showed decreasing levels of total Kjeldahl nitrogen, nitrate, chemical oxygen demand, total phosphorus, ammonia, and total suspended solids. Nitrate-nitrogen levels declined by 55 to 66 percent per year, total Kjeldahl nitrogen levels declined by 54 to 67 percent per year, and chemical oxygen demand levels declined by 44 to 67 percent per year.

Lake Shaokatan, Minnesota

Lake Shaokatan is a shallow prairie lake located in western Minnesota on the South Dakota border. The lake's water quality severely deteriorated in the 1980s as a result of excessive nutrient loading associated with watershed land-use practices. Harmful algal blooms dominated the open water season and occasionally produced algal toxins alleged to have resulted in the death of dogs and cattle. Sampling revealed extremely high levels of total phosphorus (average summer value of $270 \,\mu\text{g/L}$). Chlorophyll *a* concentrations were episodic with concentrations noted to exceed $100 \,\mu\text{g/L}$ (with summer means of 20 to $30 \,\mu\text{g/L}$). The major source of the phosphorus was attributed to swine and dairy feedlots and drain tile operations.

A complete watershed restoration project was implemented. The goal was to achieve total phosphorus levels of 90 μ g/L or less. Since late 1991, the restoration program has included the following practices relevant to animal operations, as well as a variety of other practices (such as repairing septic systems):

- diverting a stream from a swine operation; and
- upgrading a dairy feedlot operation.

The combination of the full range of practices in the watershed reduced phosphorus loading rates by 58 to 90 percent. These practices cost about \$3 to \$11 per kilogram of reduced phosphorus. The watershed's response to these corrective actions was immediate and significant, as both nutrient and sediment losses were reduced. Average summer total phosphorus concentrations dropped from 270 to 89 µg/L by 1994. Furthermore, the intensity and duration of seasonal algal blooms have been curtailed with all values now less than 20 µg/L.

Tangipahoa River, Mississippi

Animal waste from confined dairy, swine, and poultry waste lagoons is a contributing factor to the high level of nitrogen, phosphorus, and fecal coliform found in some Mississippi streams.

Waste management plans were implemented in southwestern Mississippi to help remedy water quality problems in the Tangipahoa River, which flows southeast across the Mississippi and Louisiana state lines to Lake Pontchartrain, Louisiana. The project then expanded to other districts. The plans included pumping solids from improperly functioning animal waste lagoons and applying them to the land with a traveling gun irrigation system, in accordance with waste management plans at various sites. Approved waste management plans may have also included nutrient management plans. During the project time period, 12 lagoon systems (10 dairy, one swine, and one poultry) were pumped out. The total amount of land used for the applications included 192 acres of cropland and 206 acres of pastureland. In total, the lagoon effluent irrigated onto these acres contained 72,402 pounds of nitrogen, 34,911 pounds of phosphorus, and 82,715 pounds of potassium.

The landowners who participated in the demonstration project were pleased with the outcome and saved money on fertilizer costs. They noted that the demonstration resulted in the following benefits:

- The irrigation system helps alleviate lagoon overflow problems.
- Expensive and time-consuming equipment is not necessary for the adoption of this lagoon management practice. Tank trucks and tractors, which cause soil erosion and compaction, can be eliminated.
- Production costs are significantly lower when nutrients are recycled to crop and pasture systems. The alternative practice, commercial fertilizers, is more expensive.

Crooked, Otter, and North Fork Tributaries, Missouri

This project covered an area of approximately 630 square miles in northeast Missouri, including all of the drainage area of the Crooked, Otter, and North Fork tributaries that empty into Mark Twain Lake. Agricultural land composes 55 percent of the project area's land use. The land is intensively cropped and is also a major pork producing region. Two counties within the drainage area have over 300 swine facilities and an additional 100 dairy and beef operations.

This project expedited the adoption of innovative BMPs through technical assistance to producers. The project is designed to help farmers:

- develop, implement, and evaluate total resource management (TRM) systems or whole-farm plans that emphasize nutrient and pesticide strategies;
- plan, design, and install animal waste systems; and
- provide assistance to field personnel in the formulation and implementation of TRM systems training.

The TRM plans include such practices as manure and nutrient management, intensive rotational grazing systems, alternative water supplies for livestock, waste production storage and treatment

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programs, erosion control, dead animal composting, soil and water testing, prairie restoration, woodland and wildlife management, precision farming, crop rotation, farm dump cleanups and alternatives to illegal dumping, insect scouting, weed mapping, pesticide container recycling, and nitrogen-fixing legumes for reduced fertilizer applications.

As a result of TRM plan implementation, the farms and communities reaped benefits, including improved water quality, less field and streambank erosion, more plentiful wildlife and beneficial pests, fewer chemicals and nutrients in runoff, and increased yields and income.

Godfrey Creek, Montana

Several dairy cattle, swine, and beef cattle operations are located immediately adjacent to Godfrey Creek in Montana and are the major sources of impairment to the creek. Improper grazing management, riparian area degradation, and crop farming also contribute to the problem.

A project was initiated in 1989 with two primary objectives: (1) to demonstrate agricultural BMPs that will reduce suspended solids, fecal coliform, and nitrates in runoff from dairy operations, grazing, and farming practices; and (2) to develop an education program for producers in the watershed. Over 80 percent of landowners in the area participated in major efforts such as fencing riparian areas, adopting improved grazing systems, removing livestock from riparian areas, establishing buffer zones, improving manure-handling systems, and improving irrigation water management.

Post-project data, from samples taken in 1995 and 1996, suggest that water in Godfrey Creek watershed improved as a result of project activity. Estimated reductions in mean annual concentrations were 58 percent for total phosphorus and 64 percent for total dissolved solids compared with pre-project conditions. A dramatic decline (82 percent) in fecal coliform also occurred. However, nitrate-plus-nitrite data show an average increase of 24 percent. Although the project has not yet reached its goal of 80 percent reduction in these key indicators (except for fecal coliform), it is successfully helping landowners gain control of factors that influence surface and bank erosion and nutrient runoff. Agricultural practices that help control nitrate include a combination of irrigation and manure disposal methods. Future project activities may need to emphasize these practices to ensure the full realization of Godfrey Creek's potential.

Bush River-Camping Creek Watershed, South Carolina

The Bush River-Camping Creek watershed in Newberry County, South Carolina, drains directly to Lake Murray. This 51,000-acre impoundment is used to generate power, provide a municipal water supply serving approximately 330,000 people, and provide a major recreational resource. More than 175 miles of streams run through the project area, and more than 800 ponds are located along these streams. The ponds are used for livestock watering, irrigation, and recreation.

Although land uses vary, the potential for non-point source pollution is primarily agricultural. The watershed's nearly 130,000 acres support the following uses: about 29,500 acres of cropland, 60,700 acres of forest, 22,900 acres of pasture, and 16,600 acres of development (urban, industrial, and commercial). Over 200 farmsteads are maintained in the watershed, with an

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average size of 165 acres. The farm industry is quite diversified, although the most prevalent enterprises are confined animal operations, small grain production, and row crop farming. Over 60 confined animal operations have been inventoried in the watershed. The USDA Natural Resources Conservation Service (NRCS) estimates that the watershed produces about 75,000 tons of animal waste annually.

Agricultural activities in the project area are a major influence on the streams and ponds in the watershed, and contribute to nutrient-related water quality problems in the headwaters of Lake Murray. In fact, bacteria, nutrients, and sediment from soil erosion are the primary contaminants affecting these resources. The NRCS has calculated that soil erosion, occurring on over 13,000 acres of cropland in the watershed, ranges from 9.6 to 41.5 tons per acre per year. At times, excessive amounts of nutrients, especially nitrates, are found in the water, primarily as a result of land applying too much manure, sometimes with or in addition to commercial fertilizers. Based on these conditions, the Bush River-Camping Creek watershed was identified in the South Carolina Non-point Source Management Plan as a high priority watershed.

A coordinated multiple agency effort to control these non-point sources began in 1990. Phase one of the project demonstrated agricultural BMPs, provided technical assistance to agricultural landowners implementing non-point source pollution controls, financial assistance to qualifying landowners for BMP installations, and a water quality monitoring program. Simultaneously, the state inventoried and inspected all confined animal facilities in the watershed. Technical assistance was then provided to owners who were not in compliance with regulations. Potential violations include illegal discharge pipes, overflow discharges, high vegetation around lagoons, runoff from animal housing, improper dead animal disposal, and absence of permits. Phase two of the project concentrates on confined animal operations in the watershed. Components include demonstration of innovative BMPs, such as lagoon pump-out/irrigation practices and dead bird composting. Farmers in the project area have access to a mobile nutrient testing service, which helps them calculate the right amount of manure to apply to their fields and pastures, and additional computerized information to help them make prudent decisions about pesticide selection and management. Educational activities include newsletters, workshops, field days, and one-on-one technical assistance to farmers.

Several improvements have been noted since the implementation of this project:

• Ambient water quality samples gathered between May and October 1992 from the headwaters of Lake Murray, which receives water from the Bush River-Camping Creek watershed, indicated statistically significant reductions in nutrients (nitrate-nitrite and total phosphorus) since the start of the project. These decreases might be associated with reduced numbers of nutrients reaching the waterbody from non-point sources. Similar data gathered between 1992 and 1996 indicate continued reductions in nitrate-nitrite.

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- Of 48 AFOs that were out of compliance with regulations at the beginning of the project, 26 of these operations were in compliance in 1993. Twenty-two others were working on gaining compliance through coordination with state and local entities.
- Approximately 94,000 tons of soil in the watershed were saved through the use of BMPs. Also, 75,000 tons of animal waste are being properly used annually according to South Carolina guidelines (i.e., application rates, slopes, and time of year).

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